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SILENT SPEECH DURING SILENT READING.

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EFFORTS WERE MADE IN THIS STUDY TO (1) RELATE THE AMOUNT OF SILENT SPEECH DURING SILENT READING TO LEVEL OF READING PROFICIENCY, INTELLIGENCE, AGE, AND GRADE PLACEMENT OF SUBJECTS, AND (2) DETERMINE WHETHER THE AMOUNT OF SILENT SPEECH DURING SILENT READING IS AFFECTED BY THE LEVEL OF DIFFICULTY OF PROSE READ AND BY THE READING OF A FOREIGN LANGUAGE. THREE EXPERIMENTS WERE CONDUCTED. FOR THE FIRST EXPERIMENT 36 VACATION BIBLE SCHOOL CHILDREN BETWEEN 6 AND 11 YEARS OF AGE WERE INVOLVED. EXPERIMENT 2 INVOLVED 60 CHILDREN FROM A PUBLIC ELEMENTARY SCHOOL, AND IN THE THIRD EXPERIMENT, 24 FEMALE COLLEGE STUDENTS SERVED AS SUBJECTS. PRIOR TO CARRYING OUT THE EXPERIMENTS, SUBJECTS WERE CLASSIFIED BY READING AND IQ LEVELS, AGE, AND GRADE PLACEMENT. DISA SURFACE ELECTRODES RECORDED CHIN ACTIVITY IN THE FIRST EXPERIMENT. LIP ACTIVITY WAS RECORDED IN THE OTHER TWO EXPERIMENTS. READING MATERIAL WAS PRESENTED AT ONE END OF A VIEWING BOX AND WAS CHANGED BY A SYSTEM OF ROLLERS. MICROPHONES WERE USED TO RECORD ANY AUDIBLE SUBVOCAL SPEECH. MUSCLE ACTION AND BREATHING ACTIVITY WERE RECORDED FOR SOME SUBJECTS. IT WAS CONCLUDED THAT THE ACTIVITY OF SILENT READING EITHER CONSISTS OF, OR RESULTS IN, COVERT LANGUAGE RESPONSES (DEVOTED BY THE TERM "SILENT SPEECH" AS MEASURED BY LIP AND CHIN MOVEMENT, AMPLIFIED SUBVOCALIZATION, AND BREATHING RATE). A TOTAL OF 12 MORE SPECIFIC CONCLUSIONS ARE DISCUSSED. (JC)

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Silent Speech During Silent Reading

Cooperative Research Project #1863

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The term "silent speech" has traditionally been of importance because of its hypothesized relevance to the "higher mental processes", especially thinking. Theories of thinking may roughly be classified as either of a peripheral or central variety. Briefly, the peripheralist position is that thinking (consciousness, etc.) is the occurrence of covert motor activity (e.g., silent speech), while the centralist position is that thinking consists of central nervous system events. Both types of theory have respectable historical backgrounds, dating at least from the period of Greek philosophy, and both continue to be prominent in contemporary writings. The work of B. F. Skinner (e.g., 1957) powerfully presents the position that thinking is responding, while Hebb (e.g., 1959) is probably the outstanding exponent of the centralist position. An analysis of such current theorizing yields the important conclusion that either thinking is entirely a response phenomenon, or that it is a central (brain) event but has numerous motor consequences. If the peripheralist is right, thought processes can be directly investigated by studying response events; if the type of centralist theory espoused by Hebb is correct, then thought processes can often be indirectly studied by means of response phenomena. Thus, either position indicates the importance of the response, especially covert language responses, for understanding higher mental processes.

Silent reading may be considered an instance of thinking in which the thought processes are controlled by specifiable external stimuli (prose). By recording silent speech that may occur during silent reading, an understanding of the general phenomenon of thinking should be enhanced. Furthermore, since silent speech during silent reading is so noticeable in the classroom, it has long presented itself as an educational

problem. Evidence for the occurrence of silent speech during silent reading is ample (Curtis, 1900; Courten, 1902; Edfeldt, 1960; Huey, 1908; Reed, 1916; etc. See also, Cole, 1938; Dolch, 1948; Tinker, 1952; and Yoakam, 1928).

Among educators essentially two opposing positions are apparent:

1) silent speech during silent reading is an activity that interferes with reading proficiency and hence techniques for reducing silent speech (the child is asked to continuously repeat a certain sentence to himself, to put his fingers in his mouth, to chew gum, his lips are taped, etc.) should lead to reading improvement; or 2) silent speech is beneficial for silent reading -- it is a "crutch" that the advanced reader uses to get over difficult passages and that the beginning reader almost always finds necessary and helpful. Writings and research findings put forward in favor of the position that silent speech hinders effective reading include those of Betts (1950), Bond and Bond (1952), Buswell (1947), Cole (1938), Durrell (1940), Gates (1947), Judd (1927), Harris (1948), and McDade (1937). Suggestions that silent speech can be decreased by training have been offered by such as Buswell (1947), Dolch (1948), McDade (1937), O'Brien (1921), and Pintner (1913). The alternative position, that silent speech is beneficial for silent reading and thus efforts at removing it should be discontinued, has been supported by Anderson and Dearborn (1952), Edfeldt (1960), and Fryer (1941).

In short, the previous consideration given to silent speech during silent reading has resulted in conflicting opinions and conflicting empirical results. Because our educational methods are to a large extent based on whether or not silent speech is viewed as desirable or necessary it is important that we reach an adequate understanding of the role of

the phenomenon in the child's learning process. Note also the relevance of silent speech not only for reading, but also for arithmetic, writing, spelling, etc.

One of the first steps in arriving at sound, research-based methods of instruction is thus the acquisition of normative data; efforts should be made to ascertain possible relationships between amount of silent speech and such variables as level of reading proficiency, intelligence, chronological age, and grade placement. Following this it is important to determine stimulus variables that affect amount of silent speech. These were the objectives of the present research. More specifically: 1) efforts were made to relate amount of silent speech during silent reading to level of reading proficiency, intelligence, chronological age, and grade placement of subjects; and 2) to determine whether amount of silent speech during silent reading is affected by the difficulty level of prose read and by reading a foreign language.

Method

Subjects. Experiment I used 36 children between six and eleven years of age who were attending a local daily vacation Bible school. Each subject received 50 cents on completion of their participation. Experiment II used 60 children from the Burlington Elementary School of the Roanoke County School System, and Experiment III used 24 female students from Hollins College. Their characteristics will be specified below.

Apparatus. Silent speech during silent reading is defined as any change in the speech mechanism occurring during silent reading, compared to activity during rest (non-reading) periods. Disa surface electrodes were used to record chin activity (Experiment I) and lip activity (Experiments II and III). The electrodes led into two Tektronix Type

122 low level amplifiers, placed in series, and recordings were made on a Model 1406 Honeywell Visicorder. A paper speed of .2 inches per second was used for all subjects.

Reading material was presented by means of a viewing box (Fig. 1). A microphone was mounted in the viewing box, and concealed from the subject by means of radio speaker cloth. In Experiment I a "Walkie-Talkie" microphone was used, and the sound was amplified by a Sanborn Model 350-1700 B Heart Sound Preamplifier. In Experiments II and III an RCA Type BK 1A microphone was used. In both cases audible subvocal speech was recorded on an Ampex 601 tape recorder, using Scotch Magnetic tape #120-12. While both audio systems were quite sensitive, that used in Experiments II and III is more so and relies solely on amplification provided by the Ampex 601.

A portable electrostatic cage constructed of a wooden frame and copper window screening mesh was used for housing the subjects for Experiment I, but was not necessary for Experiments II and III due to refinements later effected in the laboratory.

A diagram of the experimental rooms is presented in Fig. 2. It can be seen that the room containing the apparatus was separate from that in which the subject was placed. Both rooms were sound-deadened, thereby providing excellent recording conditions. The window between the two rooms allowed the subject to be observed by the experimenter running the apparatus.

Procedure. All elementary school subjects were administered the California Reading Test, Form W, and the Kuhlman Anderson Test, 6th Edition. The total score on the former was used as an estimate of reading proficiency, and an intelligence quotient was obtained from the

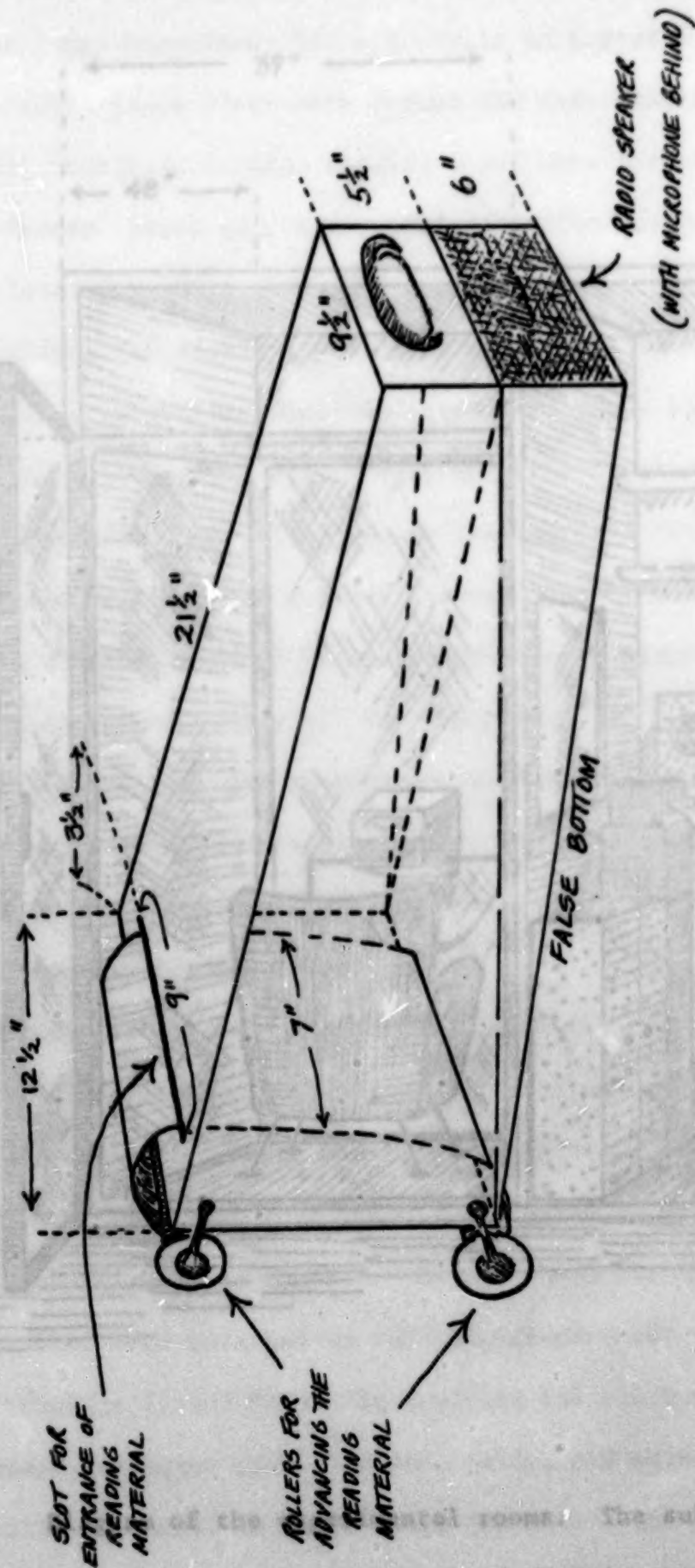


Fig. 1. Viewing box used for presenting reading material. The subject looked through the aperture to the right.

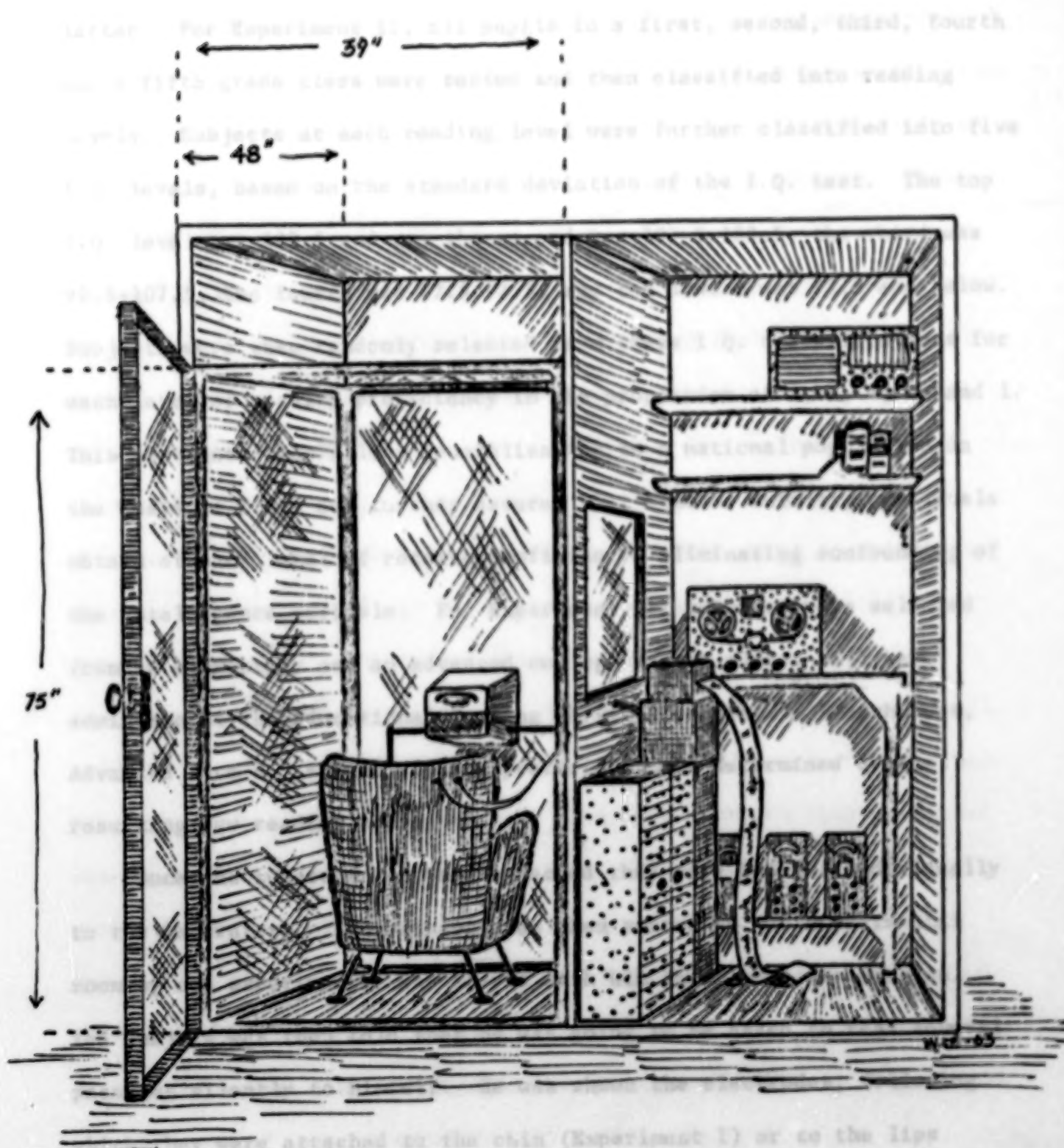


Fig. 2. Diagram of the experimental rooms. The subject and one experimenter were to the left. A second experimenter ran the apparatus in the room to the right.

latter. For Experiment II, all pupils in a first, second, third, fourth and a fifth grade class were tested and then classified into reading levels. Subjects at each reading level were further classified into five I.Q. levels, based on the standard deviation of the I.Q. test. The top I.Q. level was 122.5 and up, the second was 107.5-122.5, the third was 92.5-107.5, the fourth was 77.5-92.5, and the lowest was 77.5 and below. Subjects were then randomly selected from these I.Q. classifications for each level of reading proficiency in the proportion of 1, 2, 4, 2, and 1. This procedure thus allows generalization to a national population on the basis of I.Q., and further assures that similar intelligence levels obtain at each level of reading proficiency, eliminating confounding of the intelligence variable. For Experiment III subjects were selected from an elementary and an advanced college French class. All were administered the Educational Testing Service Cooperative French Test, Advanced Form R. French reading proficiency was determined by the resulting raw reading score.

Once the subjects had been selected they were brought individually to the laboratory. Each subject was then seated in the experimental room by one experimenter who stayed with him throughout the session. The subject was then told that he was going to be asked to read several passages silently to himself. He was shown the electrodes, following which they were attached to the chin (Experiment I) or to the lips (Experiments II and III). In applying the electrodes, the skin was first cleansed, massaged with electrode jelly, and attached with adhesive tape. The chin placement followed Davis (no date); the lip placement had one electrode directly above one end of the mouth and the other directly below the opposite end of the mouth. In Experiment II the first subjects

had two electrodes placed on the left biceps, thus recording muscle action potentials from this region. This channel was modified for later subjects (see results section) by replacing the arm electrodes with a pneumograph, thus allowing the recording of breathing records. When the electrodes and pneumograph were placed on the subject, the viewing box was moved into place. The subject then closed his eyes and relaxed while recordings were obtained for a pre-reading (relaxation) control period. Once stable recordings were obtained, he opened his eyes and silently read the passage in the viewing box. On completion of the passage (or after 60 sec., whichever came first) the subject again relaxed for the post-reading period. The material first presented for reading was one grade level below his reading proficiency. Following completion of the rest--reading--rest sequence described above, the subject then read material appropriate for the next higher grade level, until his ceiling was reached, or until he read all levels of material. Progress was periodically checked by having the subject read aloud and answer questions about the material read. The level of difficulty of the material read was determined by the grade level of books used in the Roanoke County Public School System (Experiment I) and by standardized material (Bond et al., 1959) for Experiment II. For Experiment III all subjects read four passages of increasing difficulty in French, and two passages of increasing difficulty in English.

Quantification of the Data. (1) Lip movements -- The pre-reading, reading, and post-reading periods were quantified for each difficulty level of the prose read. For Experiment I the first and last five seconds of the Visicorder recording for each period was discarded to allow for extraneous types of overt activity that might have been aroused

by instructions, etc. The maximum amplitude of the recording from the resulting pre-reading period was then measured in centimeters. A length of the record during the reading period was then systematically specified equal in length to that of the precontrol period, this reading period following the first five seconds that were discarded. The maximum amplitude occurring during this portion of the reading period was then measured. Any tracing marked (during the experimental session) as an overt movement (swallowing, talking aloud, licking the lips, movement of the body or head, etc.), or which could clearly be regarded as an overt movement was discarded from further consideration. In short, then, the maximum amplitude for lip movements was obtained for each subject at each level of difficulty of prose read for the pre-reading, reading, and post-reading periods.

(6) *Experimenter Ratings* -- The experimenter rated the amount of lip movement of the subject in the experimental situation, using the same scale as did the teacher. For Experiments II and III essentially the same procedure was followed except that the maximum amplitude of lip movements were obtained during the last 10 seconds of the pre-reading and post-reading

periods (prior to the final five seconds which were discarded), and during the middle 10 seconds of the reading period. Calibration procedures indicated that 11 cm. = 50 microvolts for Experiments II and III (Experiment I data were not calibrated).

(2) *Arm Muscle Action Potential* -- Maximum amplitudes were measured for the same periods specified for Experiment II above.

(3) *Pneumograms* -- The first and last five seconds of the records for each of the three periods were discarded; thirty seconds of the records for each period were then specified, as above, and the number of respirations occurring during each 30 seconds period was then counted. The rate was then determined as the number of respirations per minute

(4) Audible Subvocal Speech -- The tape recordings were played back in a sound-deadened room. Three raters recorded each subvocalization (whispering words or portions of words) that they heard for each subject at each level of difficulty of prose read, and the average among them computed.

(5) Teacher Ratings -- For Experiment II the teachers were asked to rate the amount of lip movement shown by their pupils in a normal classroom reading exercise. Ratings on the following scale were obtained on two different occasions, and the average computed.

Pupil's Name _____

No Lip Movement	Slight Lip Movement	Moderate Lip Movement	Much Lip Movement	Reads Aloud
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(6) Experimenter Ratings -- The experimenter rated the amount of lip movement of the subject in the experimental situation, using the same scale as did the teacher.

Results and Discussion

Reading vs. Rest Periods. To determine whether or not the various measures of silent speech increased during silent reading compared to the pre-reading and post-reading control periods, mean activity scores were computed for all subjects for all material read. The results for Experiment II are presented in Figure 3 where it may be seen that mean number of subvocalizations, mean maximum amplitude of lip movements, and mean breathing rate were greater during silent reading than during the rest periods. Limited control measures of MAP on the left arm, on the other hand, increased only slightly during the period of silent

Fig. 3 reading. It thus appears that laryngeal activity, in general, is greater during the reading as against the control (rest) periods; this arm as a function of experimental period (Experiment II).

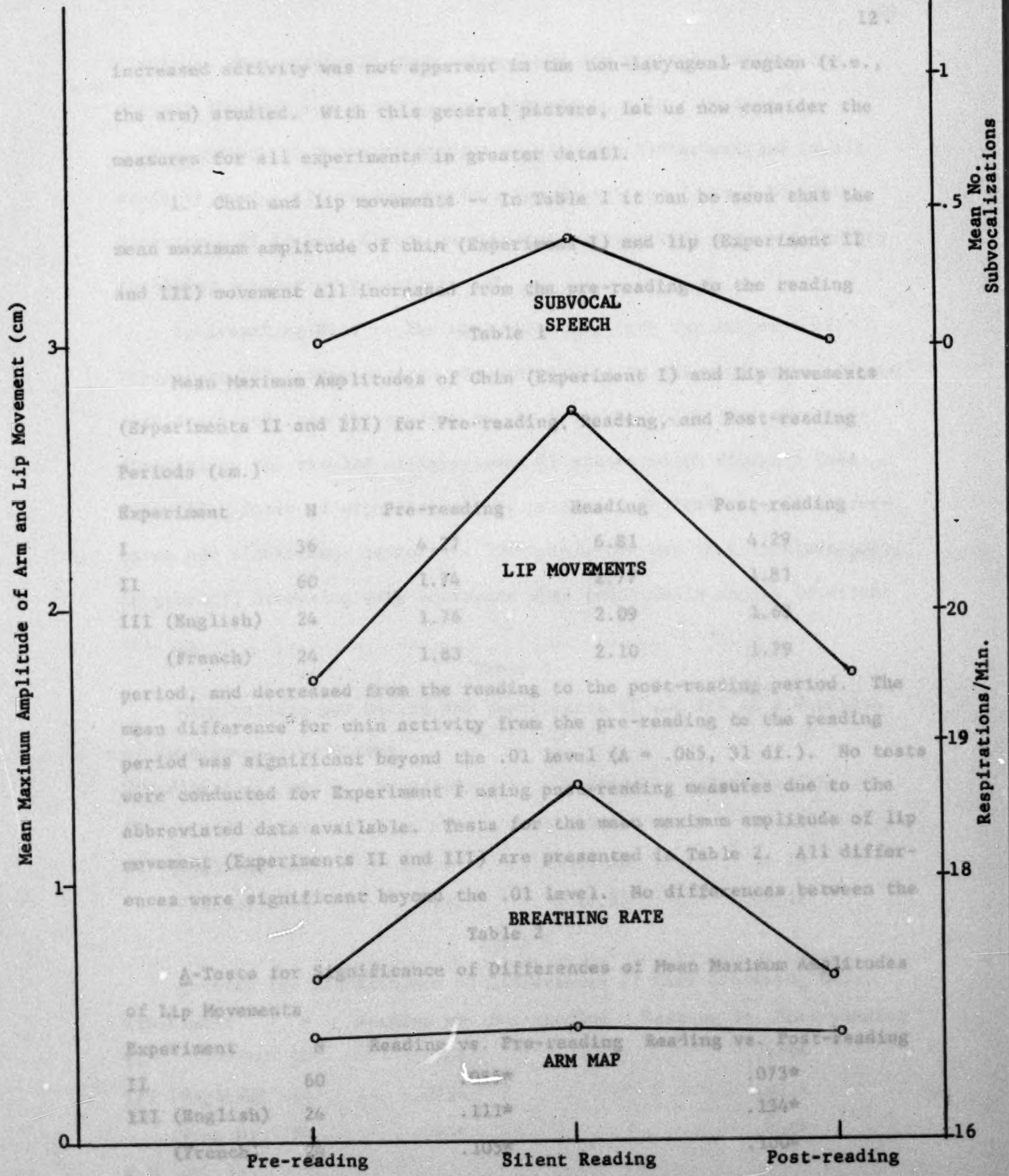


Fig. 3. The mean maximum amplitude of lip movements, the amount of subvocal speech, breathing rate and mean maximum amplitude of muscle action potential from the left arm as a function of experimental period (Experiment II).

increased activity was not apparent in the non-laryngeal region (i.e., the arm) studied. With this general picture, let us now consider the measures for all experiments in greater detail.

1. Chin and lip movements -- In Table 1 it can be seen that the mean maximum amplitude of chin (Experiment I) and lip (Experiment II and III) movement all increased from the pre-reading to the reading

Table 1
Mean Maximum Amplitudes of Chin (Experiment I) and Lip Movements (Experiments II and III) for Pre-reading, Reading, and Post-reading Periods (cm.)

Experiment	N	Pre-reading	Reading	Post-reading
I	36	4.27	6.81	4.29
II	60	1.74	2.77	1.81
III (English)	24	1.76	2.09	1.68
(French)	24	1.83	2.10	1.79

period, and decreased from the reading to the post-reading period. The mean difference for chin activity from the pre-reading to the reading period was significant beyond the .01 level ($A = .065$, 31 df.). No tests were conducted for Experiment I using post-reading measures due to the abbreviated data available. Tests for the mean maximum amplitude of lip movement (Experiments II and III) are presented in Table 2. All differences were significant beyond the .01 level. No differences between the

Table 2

A-Tests for Significance of Differences of Mean Maximum Amplitudes of Lip Movements

Experiment	N	Reading vs. Pre-reading	Reading vs. Post-reading
II	60	.055*	.073*
III (English)	24	.111*	.134*
(French)	24	.105*	.100*

* $P < .01$

In summary, then, the indices show that silent speech increases pre-and post-reading periods were significant at the .05 level. These

findings, then, indicate that individuals, in general, exhibit increased lip and chin activity when engaged in silent reading.

2. Number of Subvocalizations -- The mean number emitted by all subjects during all reading periods for Experiment I was 1.53, for Experiment II it was .43 but no subvocalizations were detected for any (college) subject of Experiment III.

3. Breathing Rate -- The mean breathing rate for subjects of Experiment III increased from the pre-reading to the reading period and then decreased from the reading to the post-reading period thus substantiating the results of Experiment II presented in Figure 3 (see Table 3). Tests of significance are presented in Table 4; all differences are significant beyond the .01 level. We may thus conclude that, in general, breathing rate increases when individuals engage in silent reading.

Table 3

Respirations per Minute for Experiments II and III as a Function of Experimental Condition

Experiment	N	Pre-reading	Reading	Post-reading
II	34	17.26	18.66	17.26
III (English)	24	15.66	17.86	16.16
(French)	24	15.42	17.82	16.12

Table 4

A-Tests for Significance of Differences of Mean Breathing Rate.

Experiment	N	Reading vs. Pre-reading	Reading vs. Post-reading
II	34	.086*	.119*
III (English)	24	.075*	.081*
(French)	24	.065*	.058*

* $P < .01$

In summary, then, the indices show that silent speech increases when going from a resting to a silent reading condition, and then decreased for the easy, medium, and hard material as a function of level

decreases to a second resting condition. The phenomenon seems to be quite general among subjects, though less marked in the case of older (college) students. Even though no lip movements were observable to the naked eye in the case of the college students and even though no subvocalizations were recorded for them the more sensitive measures of lip movement (Visicorder recordings) and breathing rate indicate that they too exhibit silent speech during silent reading.

Difficulty of Material Read. The mean maximum amplitude of chin movement consistently increased as the level of difficulty of the material read increased (Fig. 4). Results of statistical test for this measure (35 df.) were as follows: between easy and medium difficulty, $A = 1.12$, $P > .05$; between easy and hard, $A = .020$, $P < .01$; between medium and hard, $A = .026$, $P < .01$.

The results for lip movements for Experiment II are shown in Figure 5. While not as dramatic as for Experiment I, amount of lip movement is greater for reading the hard and medium material than for the easy level. The statistical test results (59 df.) are: between medium and easy material, $A = .45$, $P > .05$; between hard and medium, $A = 1.46$, $P > .05$; between hard and easy, $A = 2.49$, $P > .05$.

Figure 6 presents the results for Experiment III. There it may be seen that little change in mean maximum amplitude of lip movements for college students occurs as the difficulty of French prose increases.

Figure 7 shows that the same conclusion holds when the college students read English, i.e., mean maximum amplitude of lip movements did not significantly increase as the subjects went from the relatively easy to the relatively difficult prose.

The differences between pre-reading and reading periods are presented for the easy, medium, and hard material as a function of level

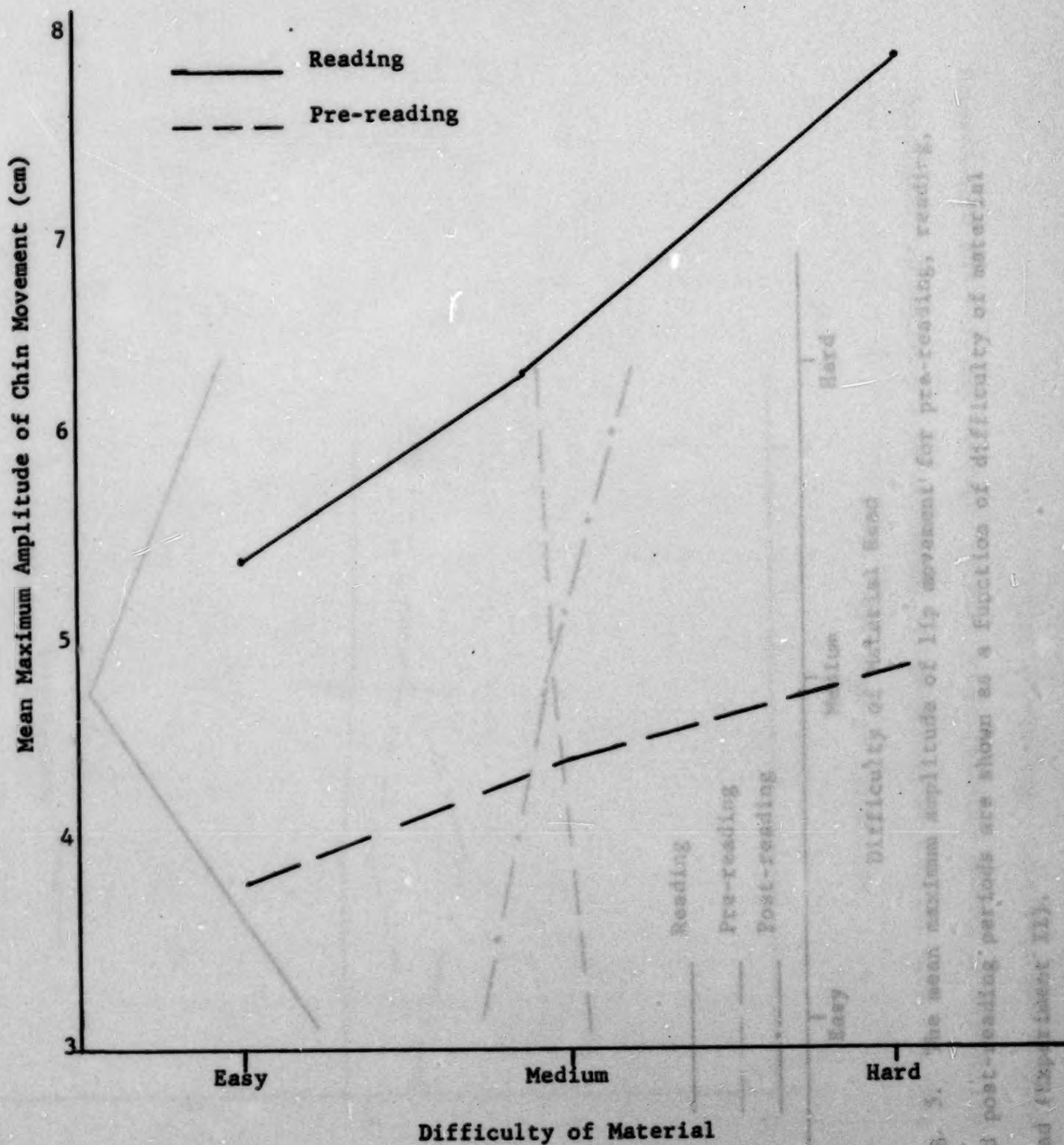


Fig. 4. Mean maximum amplitude of chin movement for pre-reading and reading periods as a function of difficulty of material read (Experiment I).

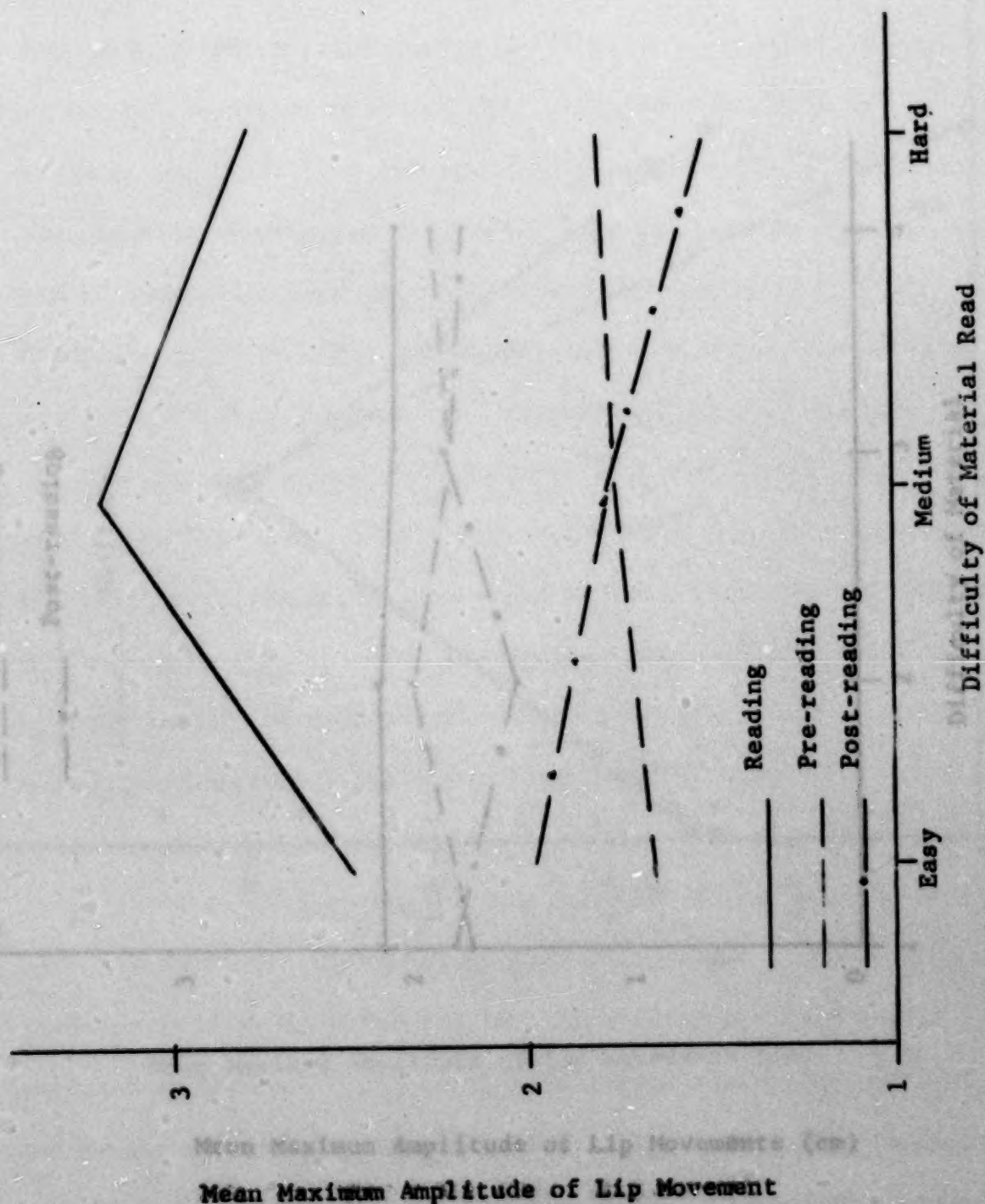


Fig. 5. The mean maximum amplitude of lip movement for pre-reading, reading, and post-reading periods are shown as a function of difficulty of material read (Experiment II).

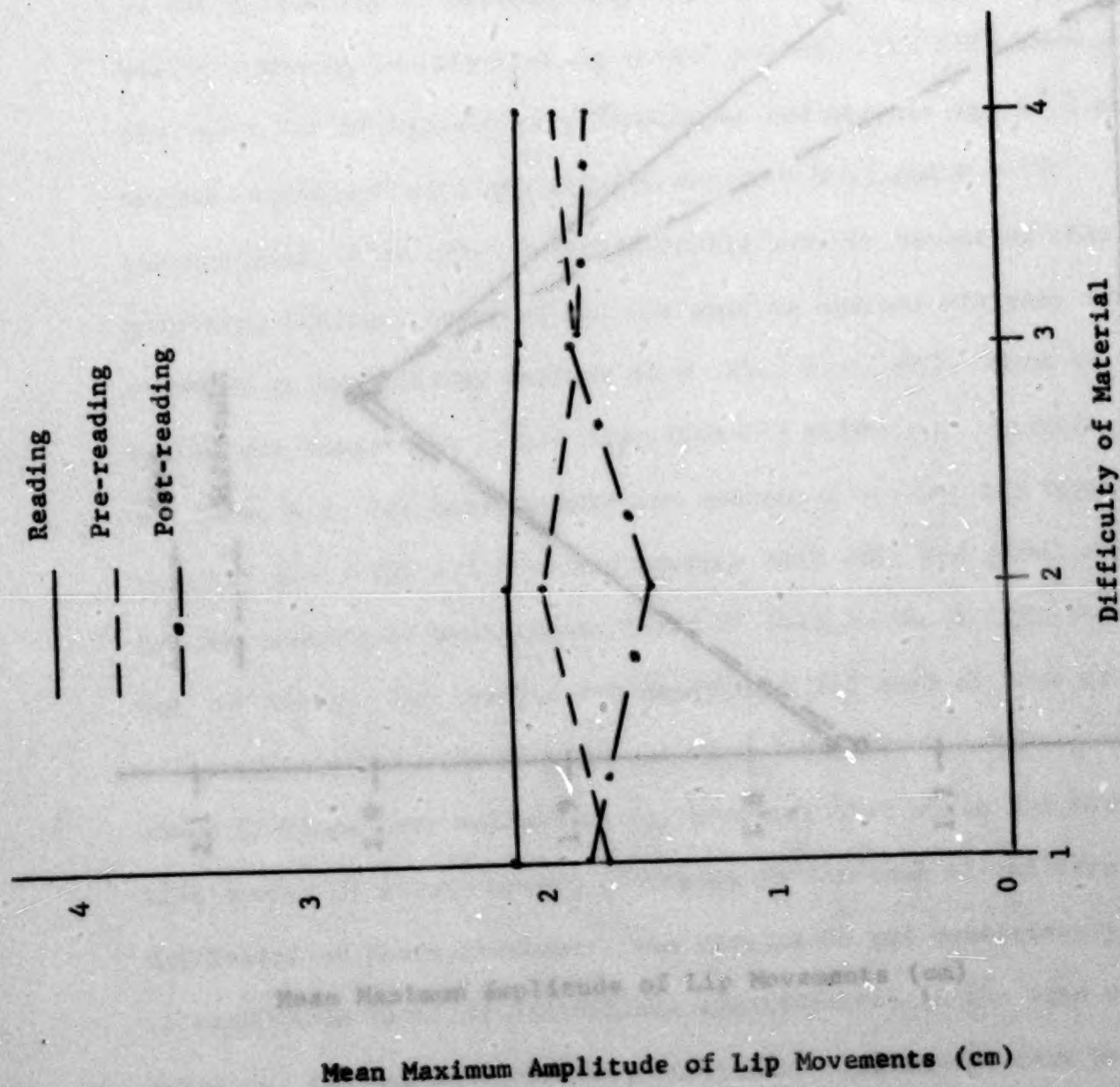


Fig. 6. Mean maximum amplitude of lip movements as a function of increasing difficulty of French material (four levels). Values for pre- and post-reading periods are also shown (Experiment III).

of reading proficiency in Figure 8 for the subjects of Experiment II. It can be seen that the major difference occurs at the lowest level of reading proficiency (grade 2) where the medium material evoked much greater lip movements than the easy and hard material.

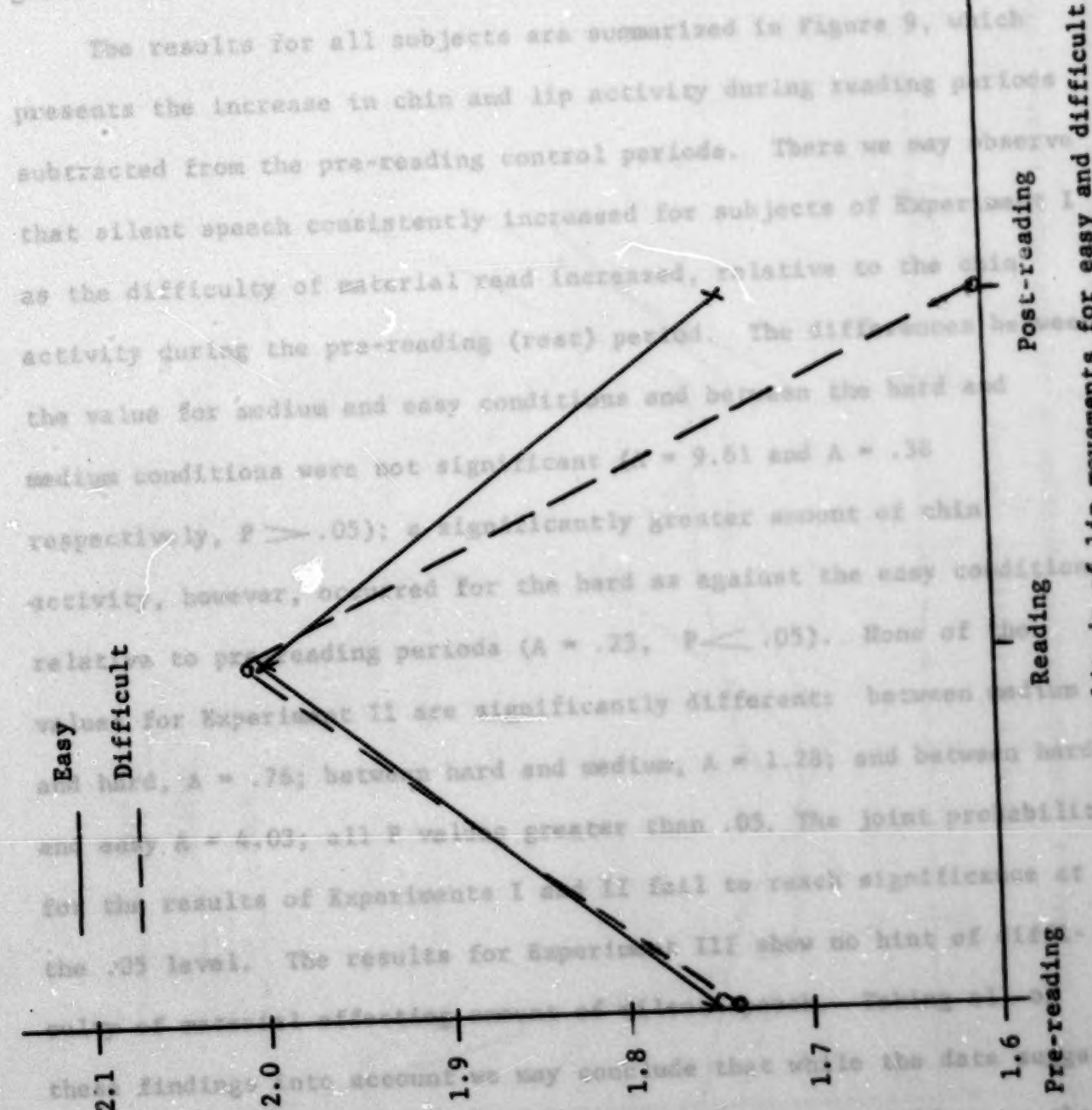


Fig. 7. Mean Maximum amplitude of lip movements for easy and difficult English material as a function of experimental period (Experiment III).

Mean Maximum Amplitude of Lip Movements (cm)

of reading proficiency in Figure 8 for the subjects of Experiment II. It can be seen that the major difference occurs at the lowest level of reading proficiency (grade 2) where the medium material evoked much greater lip movements than the easy and hard material.

The results for all subjects are summarized in Figure 9, which presents the increase in chin and lip activity during reading periods subtracted from the pre-reading control periods. There we may observe that silent speech consistently increased for subjects of Experiment I as the difficulty of material read increased, relative to the chin activity during the pre-reading (rest) period. The differences between the value for medium and easy conditions and between the hard and medium conditions were not significant ($A = 9.61$ and $A = .38$ respectively, $P > .05$); a significantly greater amount of chin activity, however, occurred for the hard as against the easy condition relative to pre-reading periods ($A = .23$, $P < .05$). None of the values for Experiment II are significantly different: between medium and hard, $A = .76$; between hard and medium, $A = 1.28$; and between hard and easy $A = 4.03$; all P values greater than .05. The joint probabilities for the results of Experiments I and II fail to reach significance at the .05 level. The results for Experiment III show no hint of difficulty of material affecting amount of silent speech. Taking all of these findings into account we may conclude that while the data suggest that amount of silent speech increases in the case of children as the difficulty of prose increases, the results do not consistently reach an acceptable level of statistical significance; in the case of older subjects, one may conclude that difficulty of material read does not affect amount of silent speech. No mean differences in breathing rate

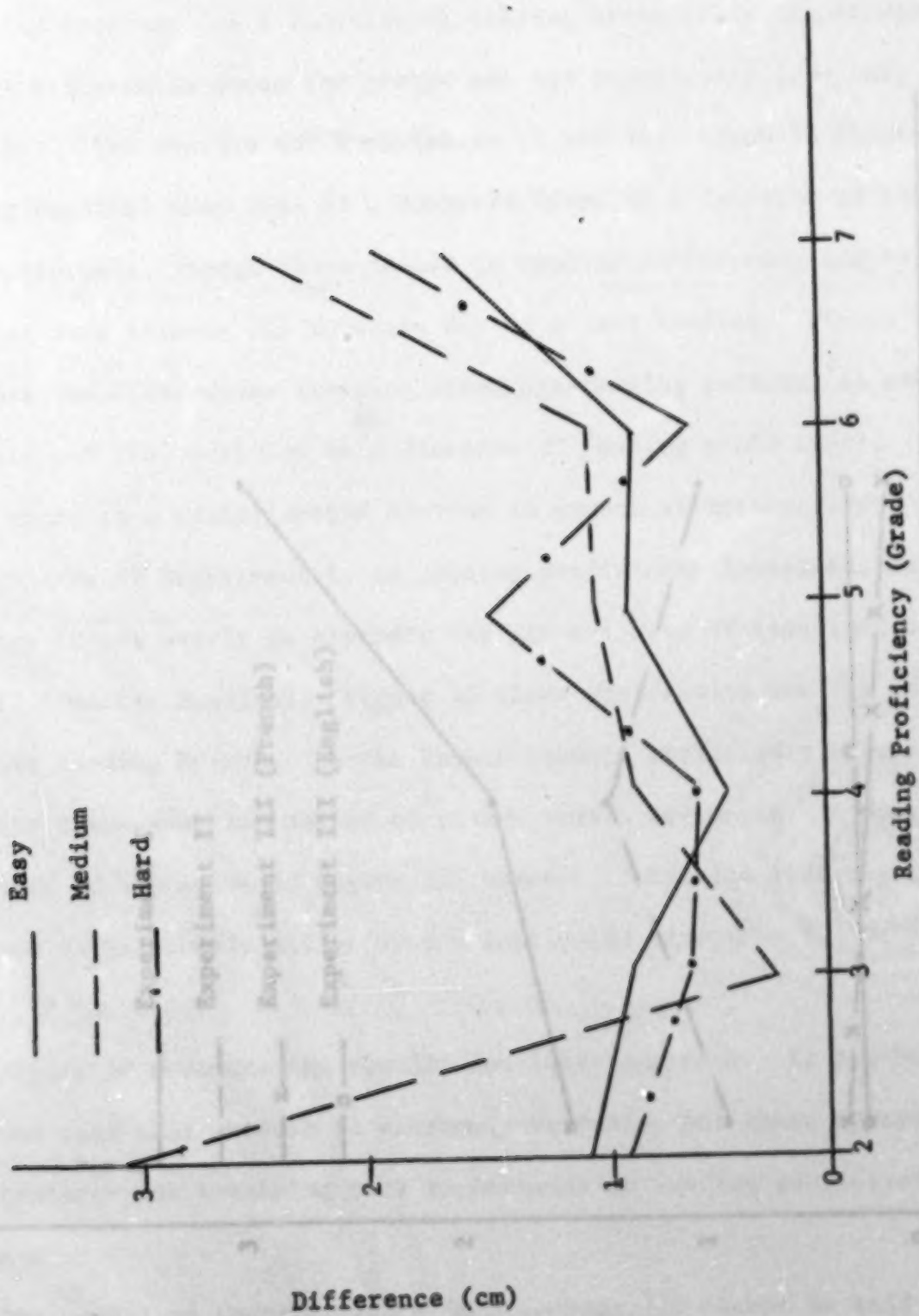


Fig. 8. Difference in mean maximum amplitude of lip movements between pre-reading and reading periods for difficulty of material read as a function of reading proficiency (Experiment II).

as a function of difficulty of material were significant at the .05 level.

Reading Proficiency. Figure 10 shows that the amount of chin movement generally decreased as a function of reading proficiency (Experiment I)

but the differences among the groups are not significant ($F = .44$, $P > .05$). The results for Experiments II and III, shown in Figure 11,

(reading English) show less of a downward trend as a function of reading proficiency, though those lowest in reading proficiency exhibited

somewhat more intense lip movement during silent reading. Figure 12 presents the differences (reading minus pre-reading periods) in amount

of (chin and lip) activity as a function of reading proficiency. Again while there is a rather marked decline in amount of chin activity

the subjects of Experiment I, as reading proficiency increases, such a tendency is not nearly so apparent for the subjects of Experiments II

and III (reading English). Figure 13 shows the results for the college students reading French. The French reading proficiency of the

subjects increased as the amount of silent speech decreased. As for the slope of the curve of Figure 13, however, indicates that the curve

does not significantly differ from a horizontal line ($F = 1.13$, 1 and 22 df., $P > .05$).

Figure 14 presents the results for breathing rate. It can be observed that this measure is extremely variable, but there is a

tendency for breathing rate to decrease as reading proficiency increases.

Taking all of these findings into account, it cannot be said that it has been demonstrated that amount of silent speech decreases as

reading proficiency increases. Nevertheless, there is a suggestion in

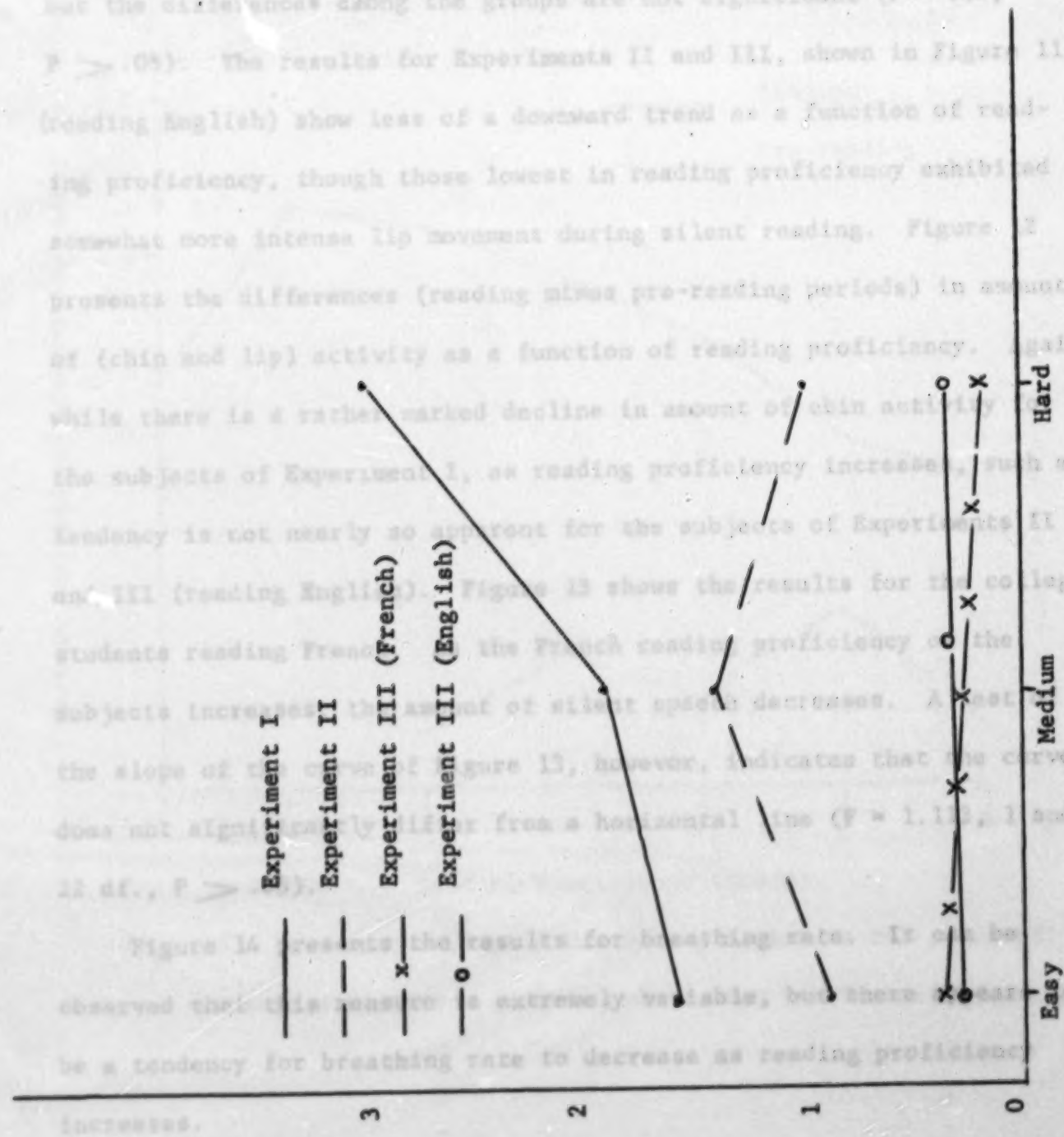


Fig. 9. Differences between pre-reading and reading periods (lip and chin movements) for all three experiments as a function of difficulty of material read.

as a function of difficulty of material were significant at the .05 level.

Reading Proficiency. Figure 10 shows that the amount of chin movement generally decreased as a function of reading proficiency (Experiment I), but the differences among the groups are not significant ($F = .44$, $P > .05$). The results for Experiments II and III, shown in Figure 11, (reading English) show less of a downward trend as a function of reading proficiency, though those lowest in reading proficiency exhibited somewhat more intense lip movement during silent reading. Figure 12 presents the differences (reading minus pre-reading periods) in amount of (chin and lip) activity as a function of reading proficiency. Again, while there is a rather marked decline in amount of chin activity for the subjects of Experiment I, as reading proficiency increases, such a tendency is not nearly so apparent for the subjects of Experiments II and III (reading English). Figure 13 shows the results for the college students reading French. As the French reading proficiency of the subjects increases, the amount of silent speech decreases. A test of the slope of the curve of Figure 13, however, indicates that the curve does not significantly differ from a horizontal line ($F = 1.113$, 1 and 22 df., $P > .05$).

Figure 14 presents the results for breathing rate. It can be observed that this measure is extremely variable, but there appears to be a tendency for breathing rate to decrease as reading proficiency increases.

Taking all of these findings into account, it cannot be said that it has been demonstrated that amount of silent speech decreases as reading proficiency increases. Nevertheless, there is a suggestion in

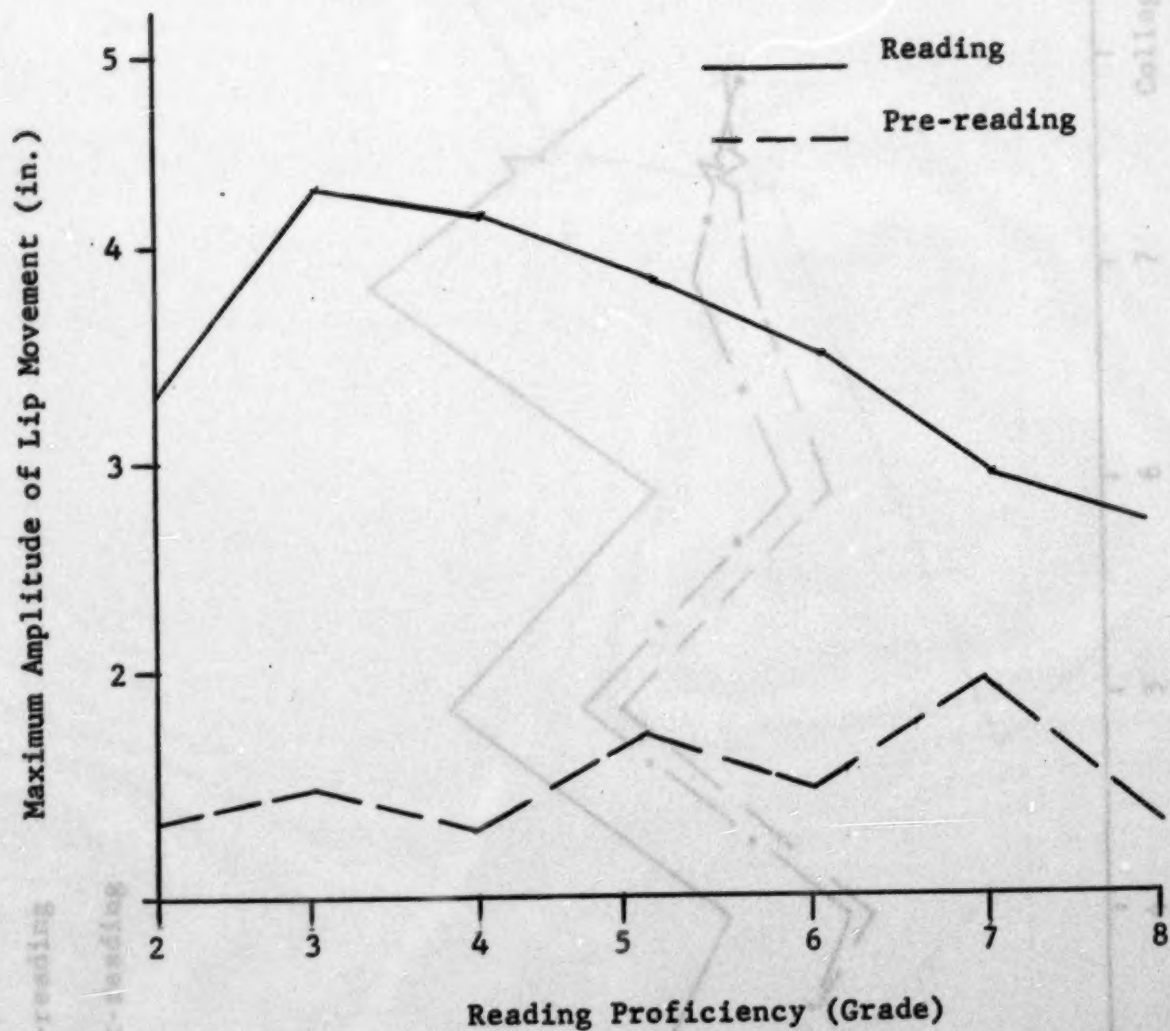


Fig. 10. Mean maximum amplitudes of lip movements for pre-reading and reading periods as a function of reading proficiency (Experiment I).

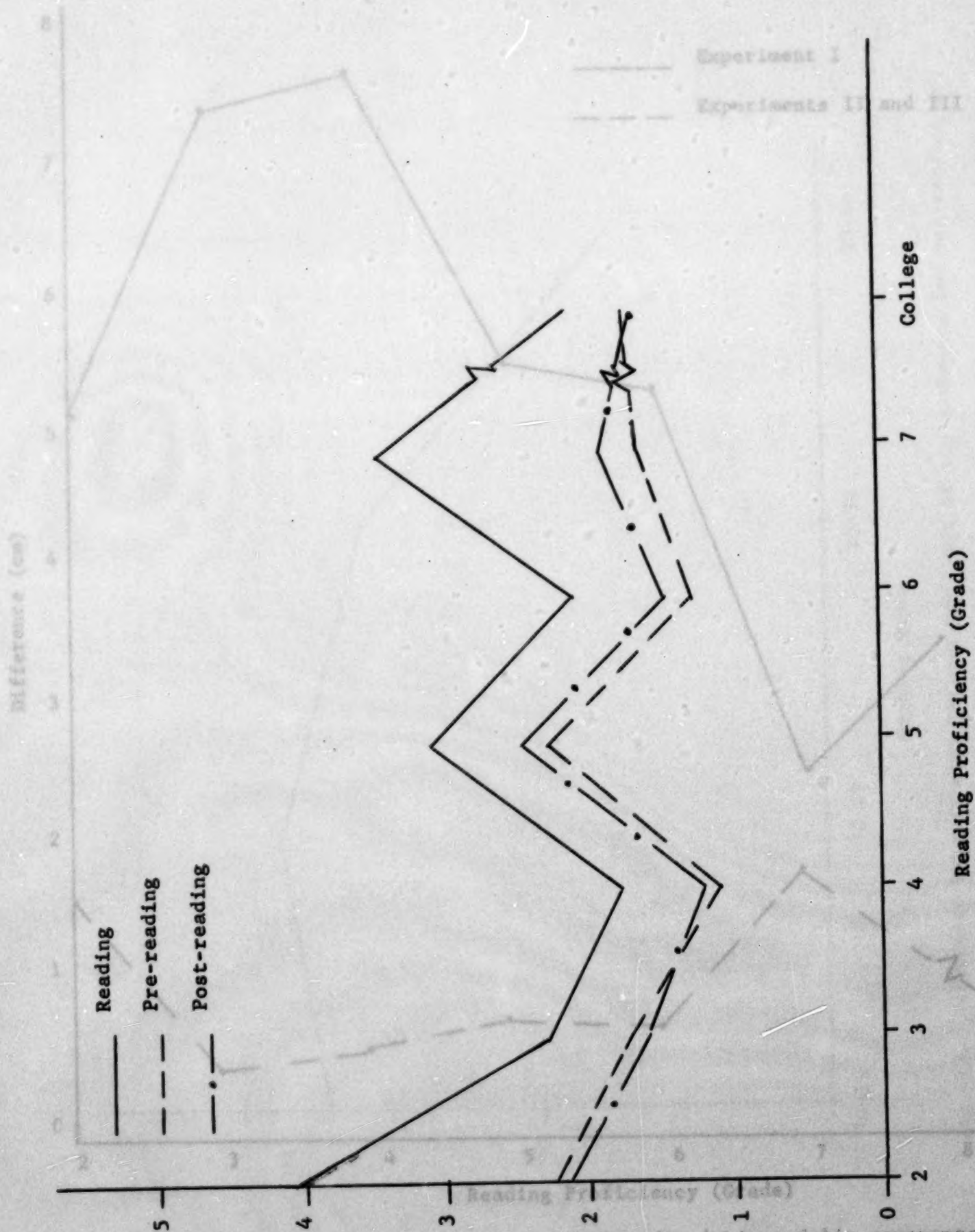


Fig. 11. Mean maximum amplitudes of lip movements for pre-reading, reading, and post-reading periods as a function of reading proficiency (Experiment II).

Fig. 12. Difference between mean maximum amplitudes (chin and lip movements) of pre-reading and reading periods as a function of reading proficiency (Experiments I, II, and III).

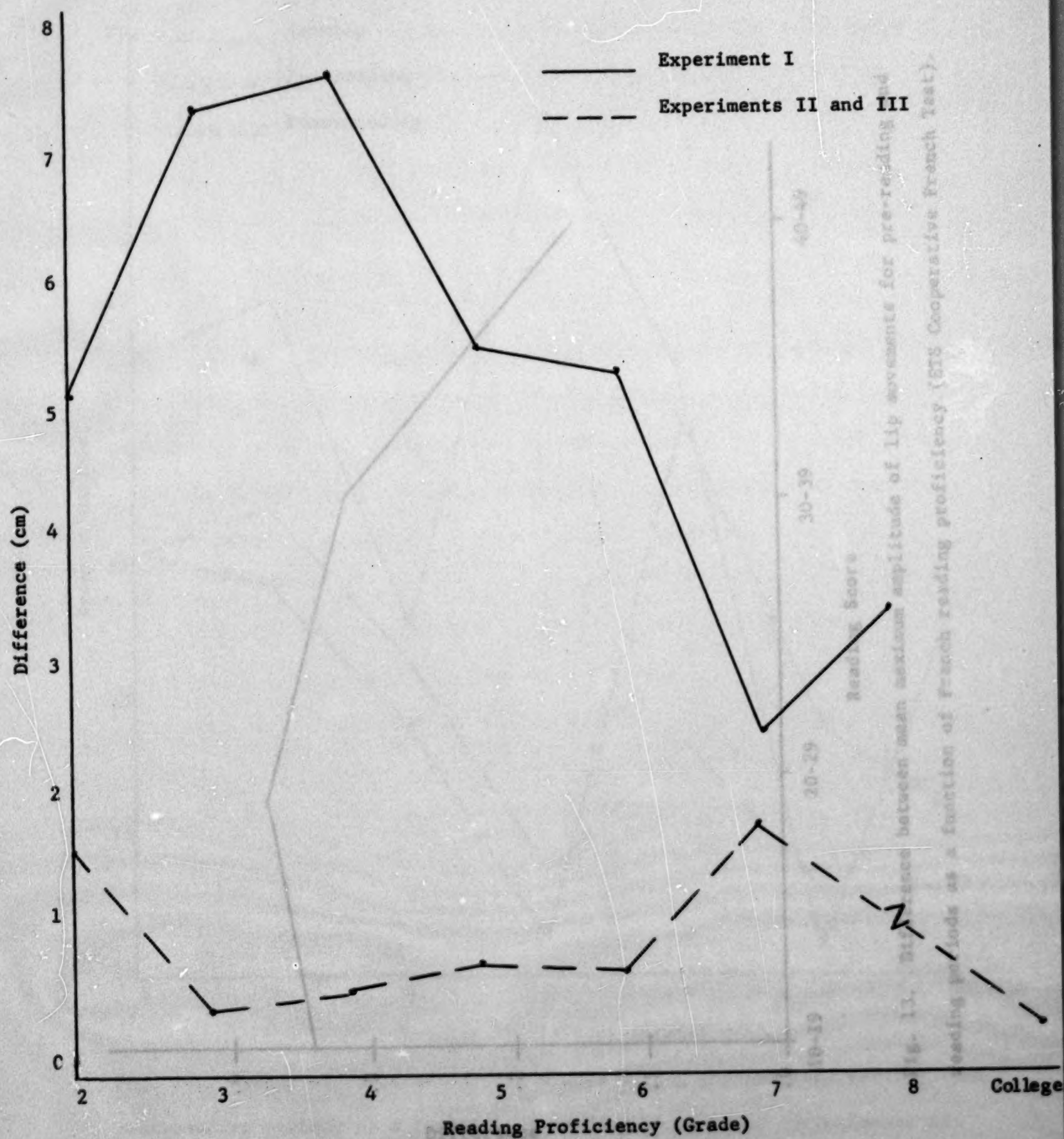


Fig. 12. Difference between mean maximum amplitudes (chin and lip movements) of pre-reading and reading periods as a function of reading proficiency (Experiments I, II, and III).

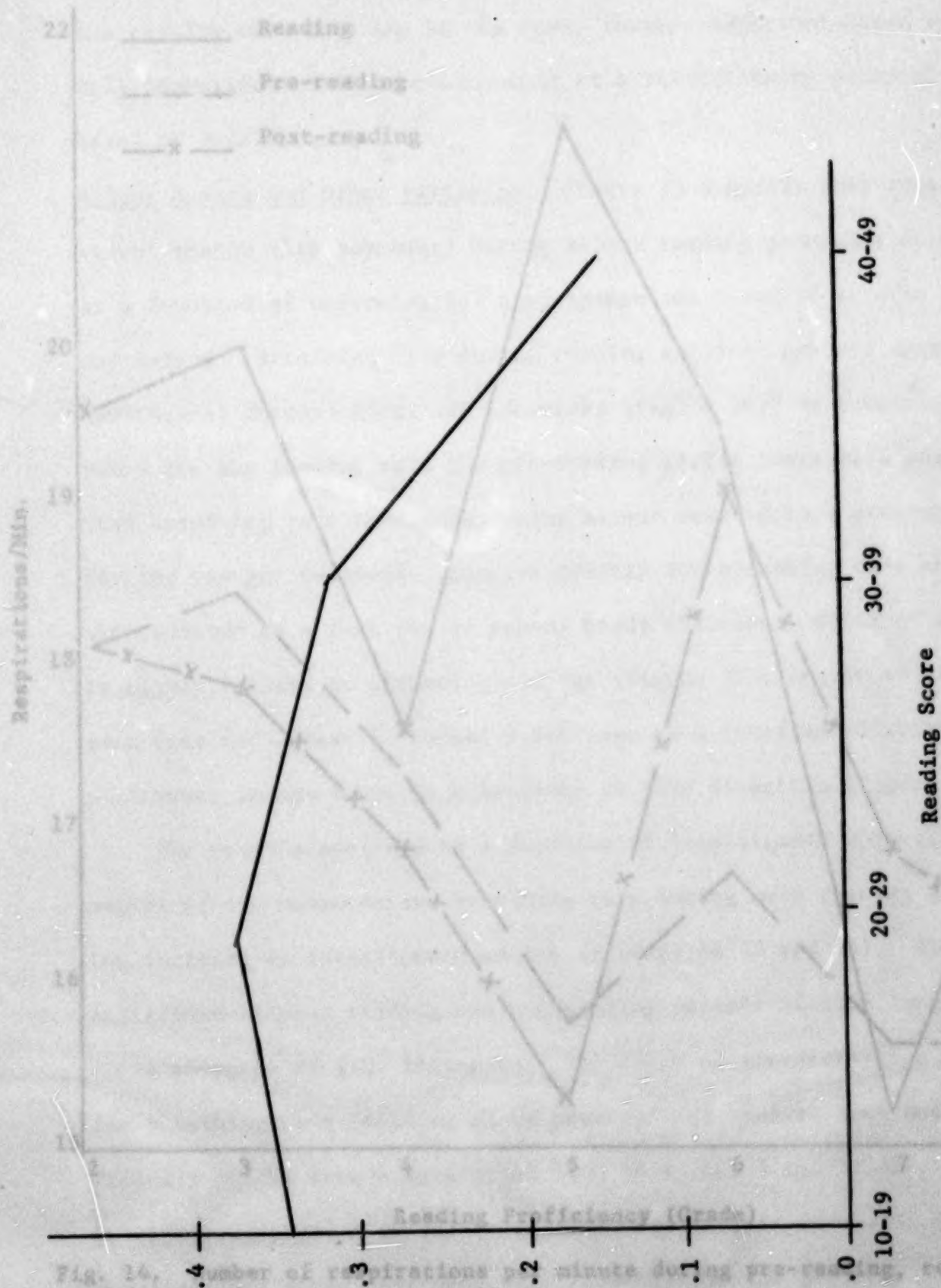


Fig. 13. Difference between mean maximum amplitude of lip movements for pre-reading and reading periods as a function of French reading proficiency (ETS Cooperative French Test).

Fig. 14. Number of respirations per minute during pre-reading, reading, and post-reading periods as a function of reading proficiency (Experiments II and III).

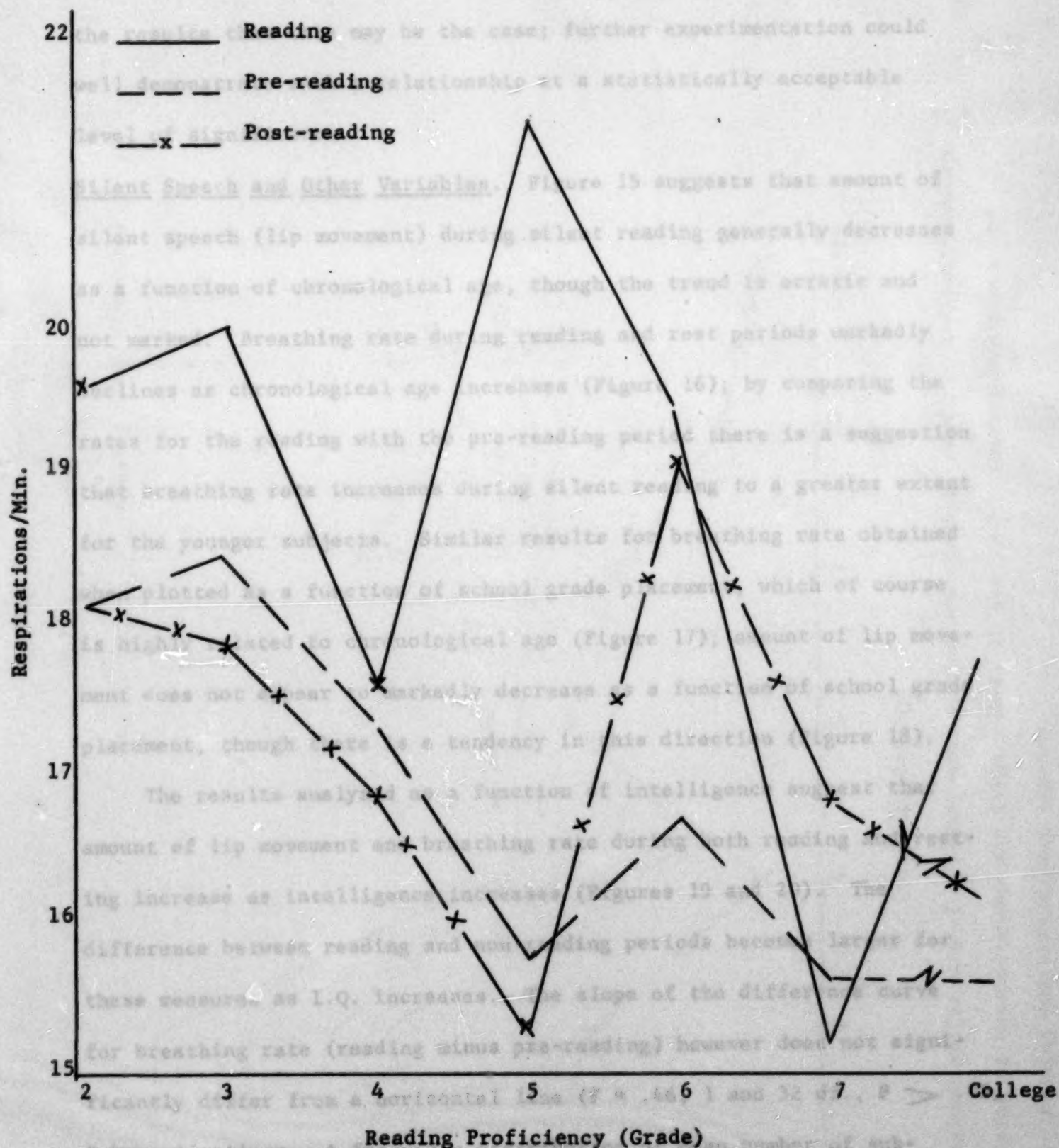


Fig. 14. Number of respirations per minute during pre-reading, reading, and post-reading periods as a function of reading proficiency (Experiments II and III).

the results that this may be the case; further experimentation could well demonstrate such a relationship at a statistically acceptable level of significance.

Silent Speech and Other Variables. Figure 15 suggests that amount of silent speech (lip movement) during silent reading generally decreases as a function of chronological age, though the trend is erratic and not marked. Breathing rate during reading and rest periods markedly declines as chronological age increases (Figure 16); by comparing the rates for the reading with the pre-reading period there is a suggestion that breathing rate increases during silent reading to a greater extent for the younger subjects. Similar results for breathing rate obtained when plotted as a function of school grade placement, which of course is highly related to chronological age (Figure 17); amount of lip movement does not appear to markedly decrease as a function of school grade placement, though there is a tendency in this direction (Figure 18).

The results analyzed as a function of intelligence suggest that amount of lip movement and breathing rate during both reading and resting increase as intelligence increases (Figures 19 and 20). The difference between reading and non-reading periods becomes larger for these measures as I.Q. increases. The slope of the difference curve for breathing rate (reading minus pre-reading) however does not significantly differ from a horizontal line ($F = .46$, 1 and 32 df., $P > .05$).

Subvocalizations. A frequency distribution of mean number of subvocalizations shows that none were recorded for the majority of subjects of Experiment II (Figure 21). Figure 22 shows that those subjects who exhibited the largest amount of lip movement in the classroom (as judged by the teacher) also showed the largest amount of lip movement

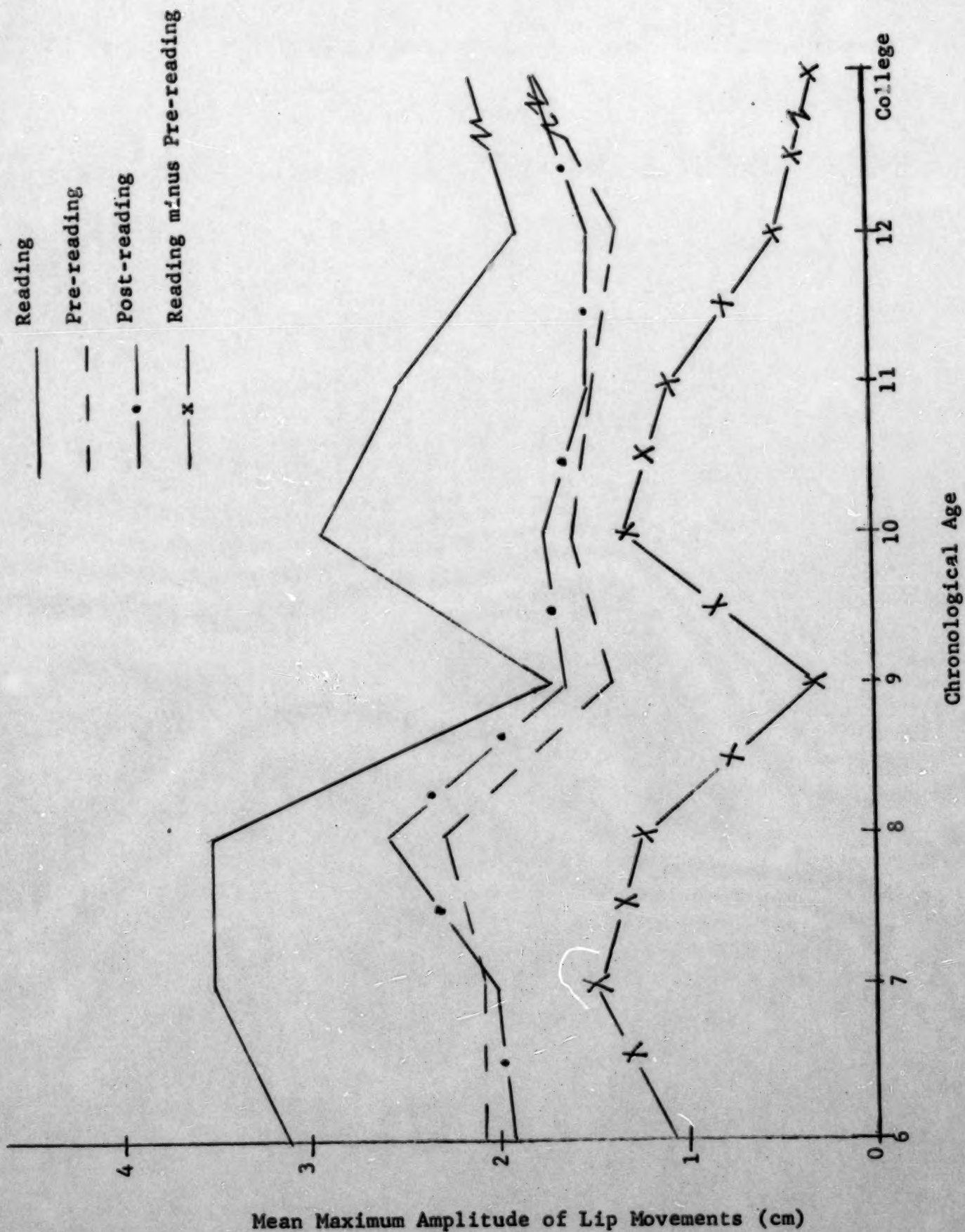


Fig. 15. Mean maximum amplitudes of lip movements during pre-reading, reading, and post-reading periods as a function of chronological age (Experiments II and III). Lower curve shows the difference between reading and pre-reading periods.

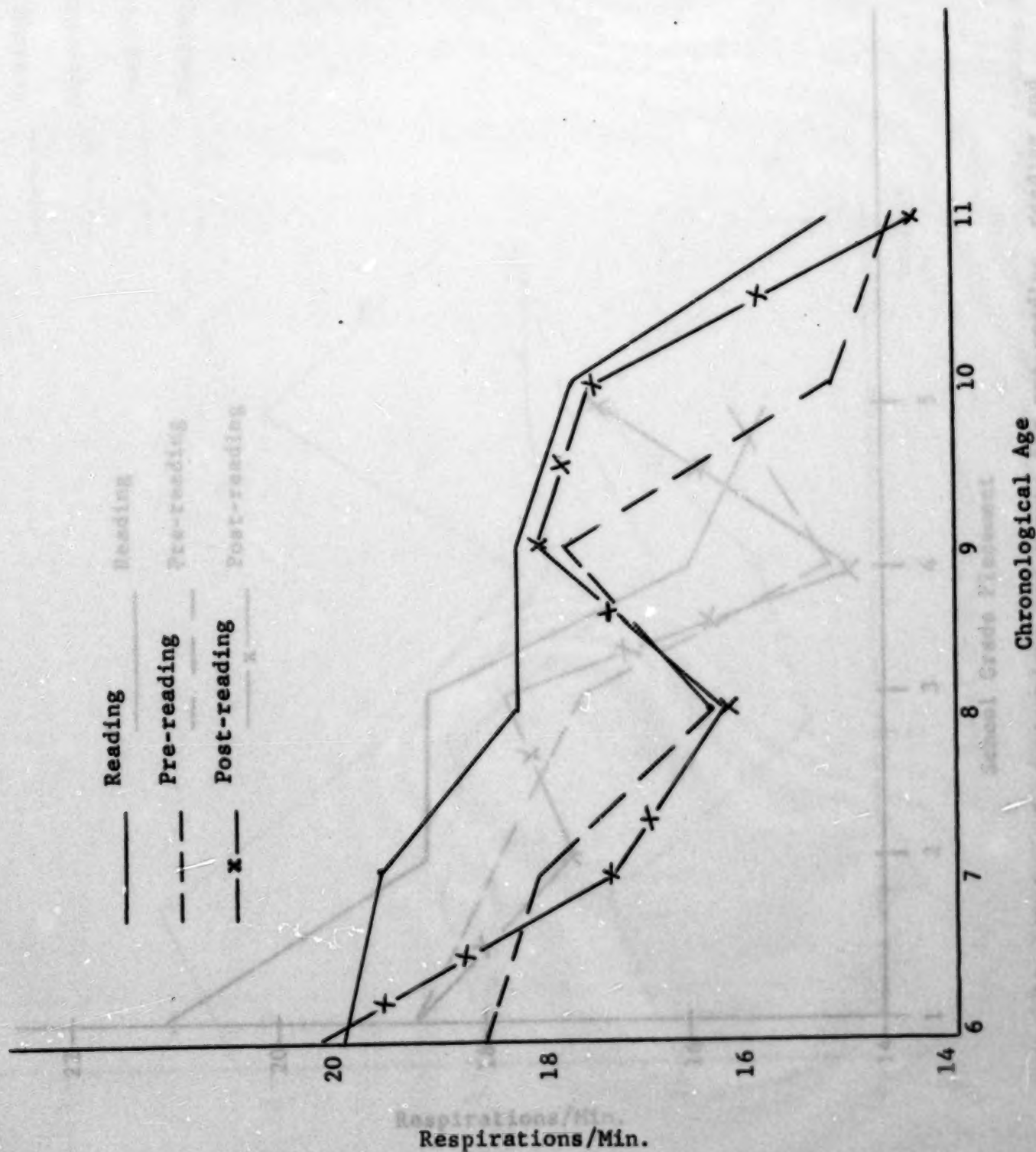


Fig. 16. Number of respirations per minute for pre-reading, reading and post-reading periods as a function of chronological age (Experiment II).

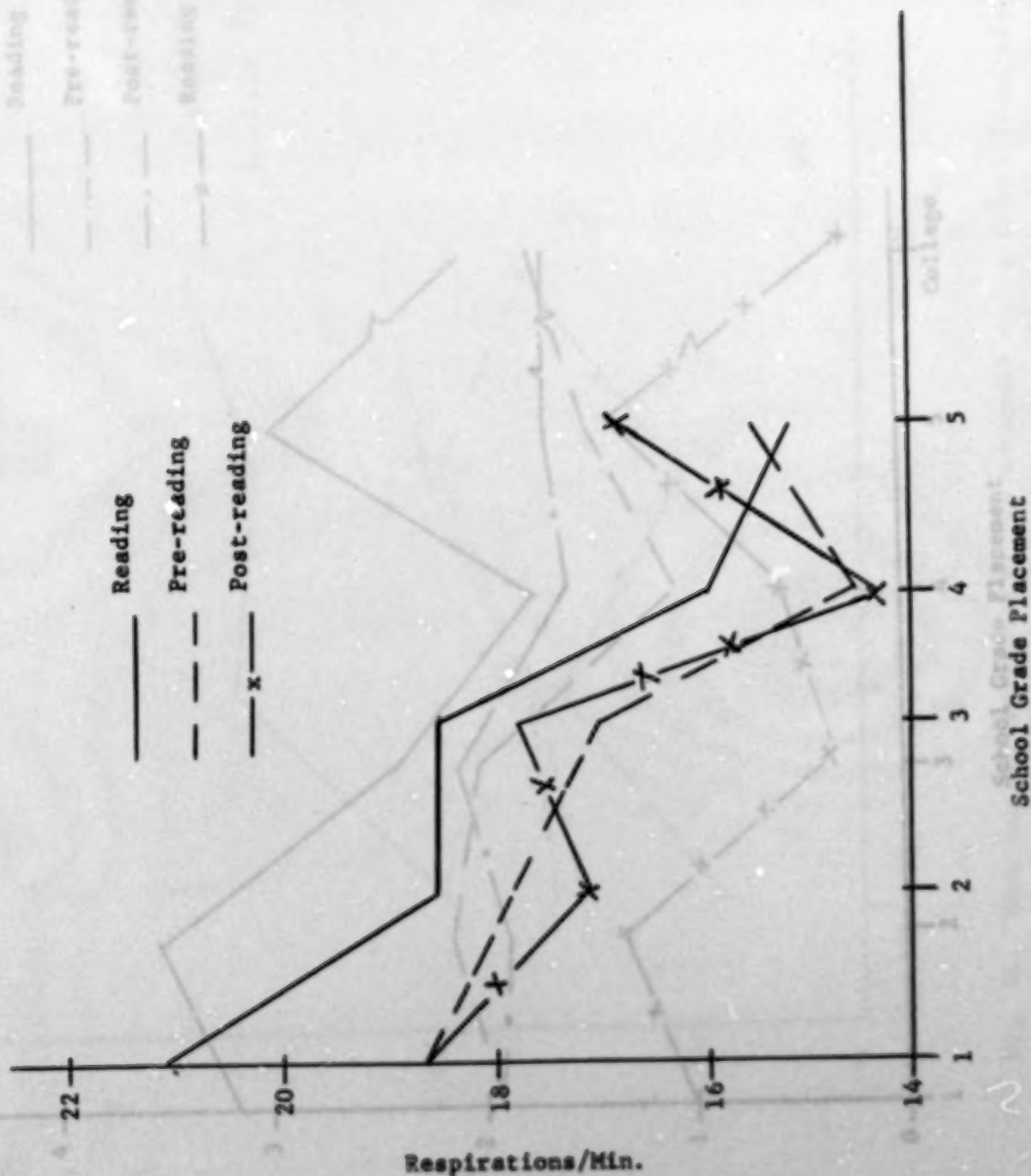


Fig. 17. Number of respirations per minute for pre-reading, reading and post-reading periods as a function of school grade placement (Experiment II).

Differences between reading and pre-reading periods is shown in lower column.

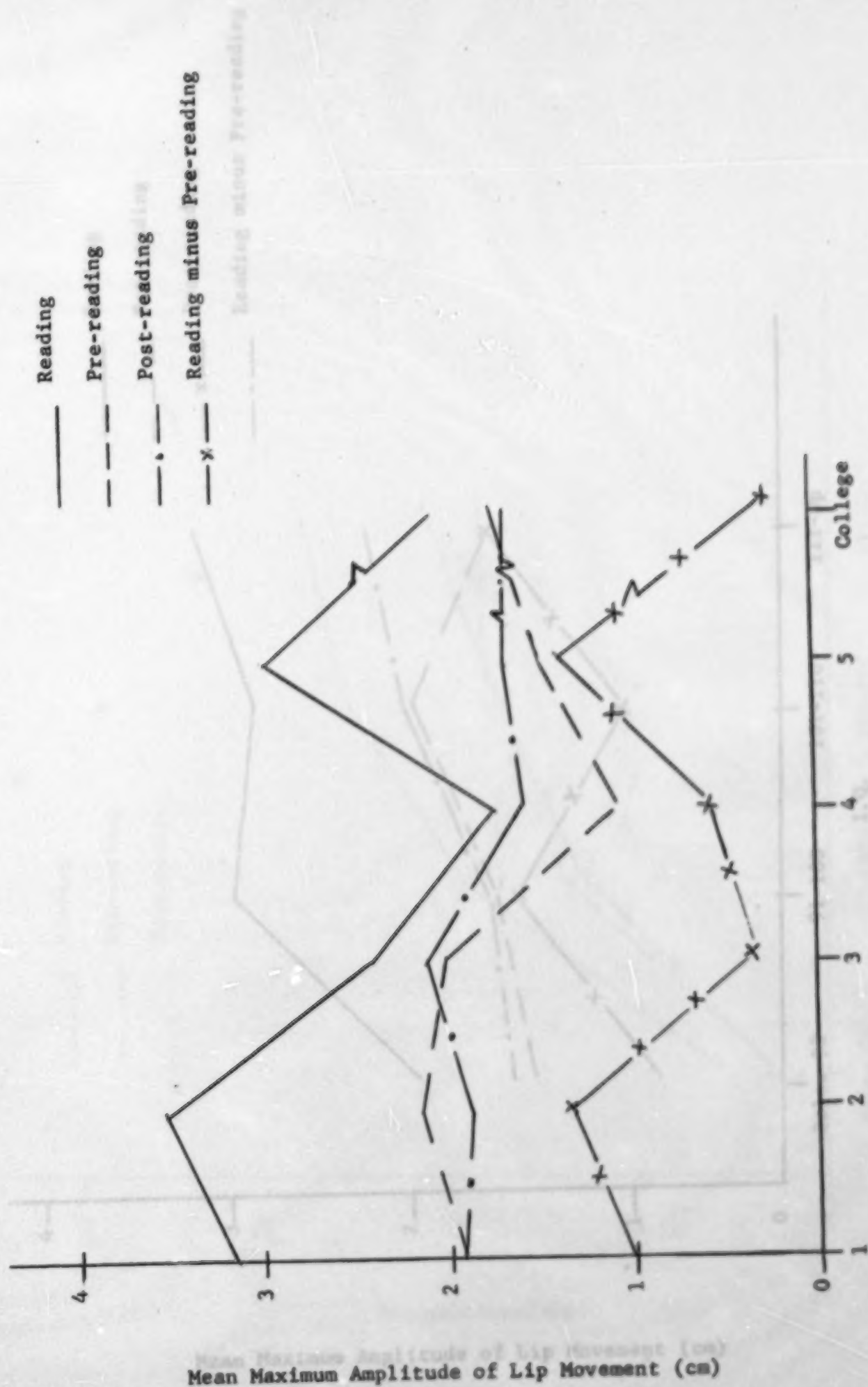


Fig. 18. Mean maximum amplitudes of lip movements during pre-reading, reading, and post-reading periods as a function of grade placement in school (Experiments II and III). Difference between reading and pre-reading periods is shown in lower curve.

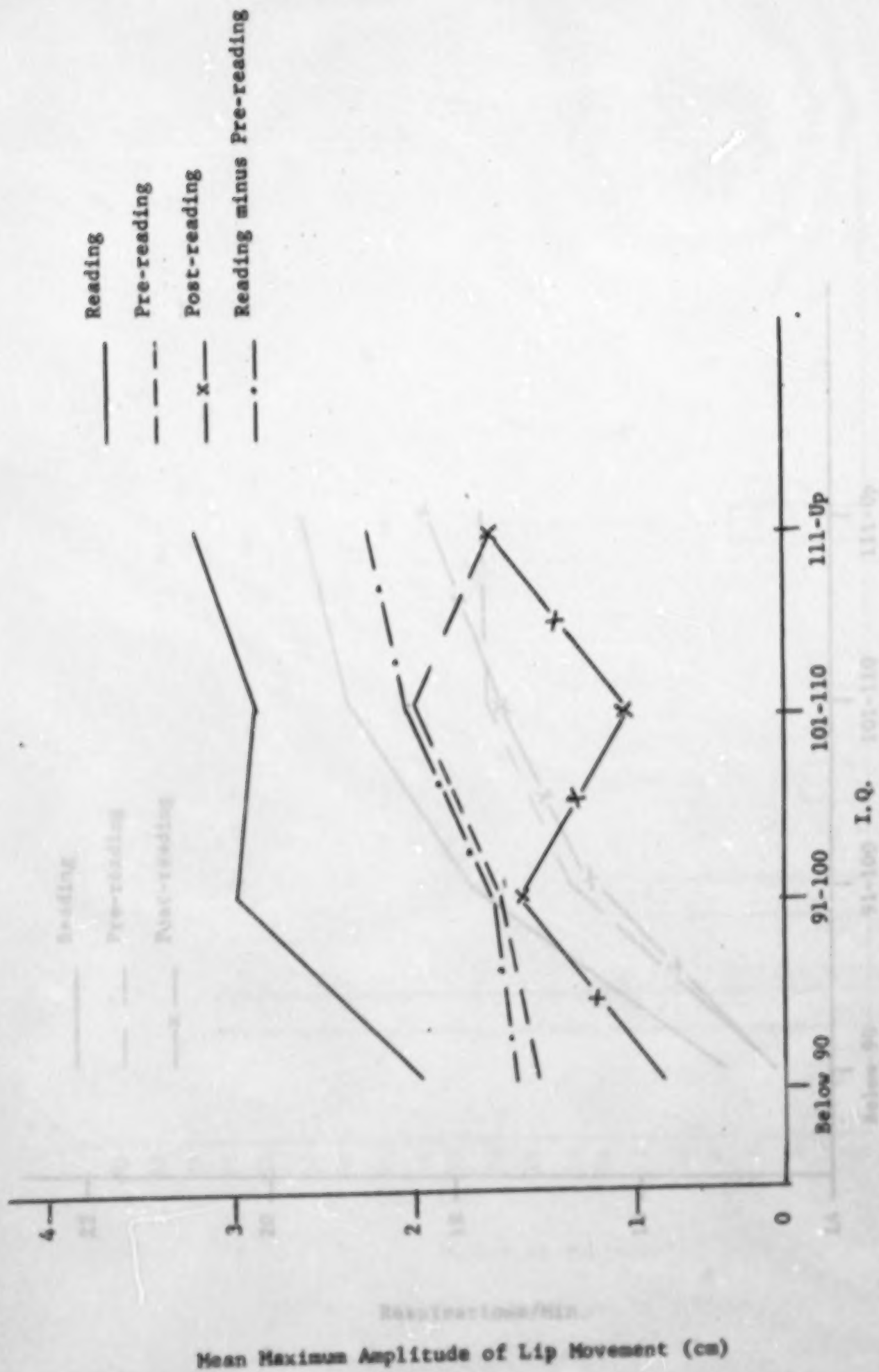


Fig. 19. Mean maximum amplitudes of lip movements during pre-reading, reading, and post-reading periods as a function of I.Q. (Experiment II). Lower curve shows the difference between reading and pre-reading periods.

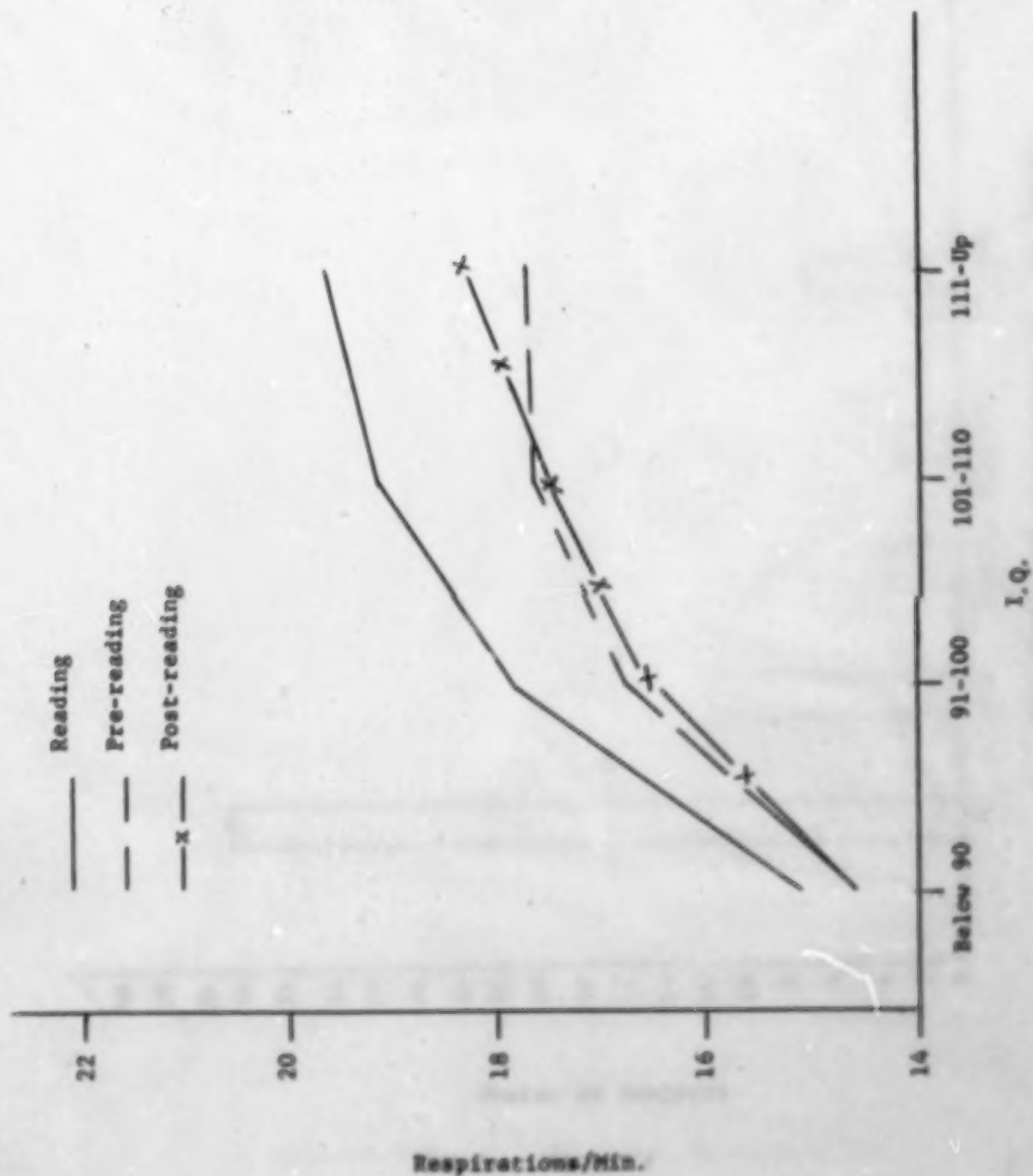


Fig. 20. Number of respirations per minute for pre-reading, reading, and post-reading periods as a function of I.Q. (Experiment II).

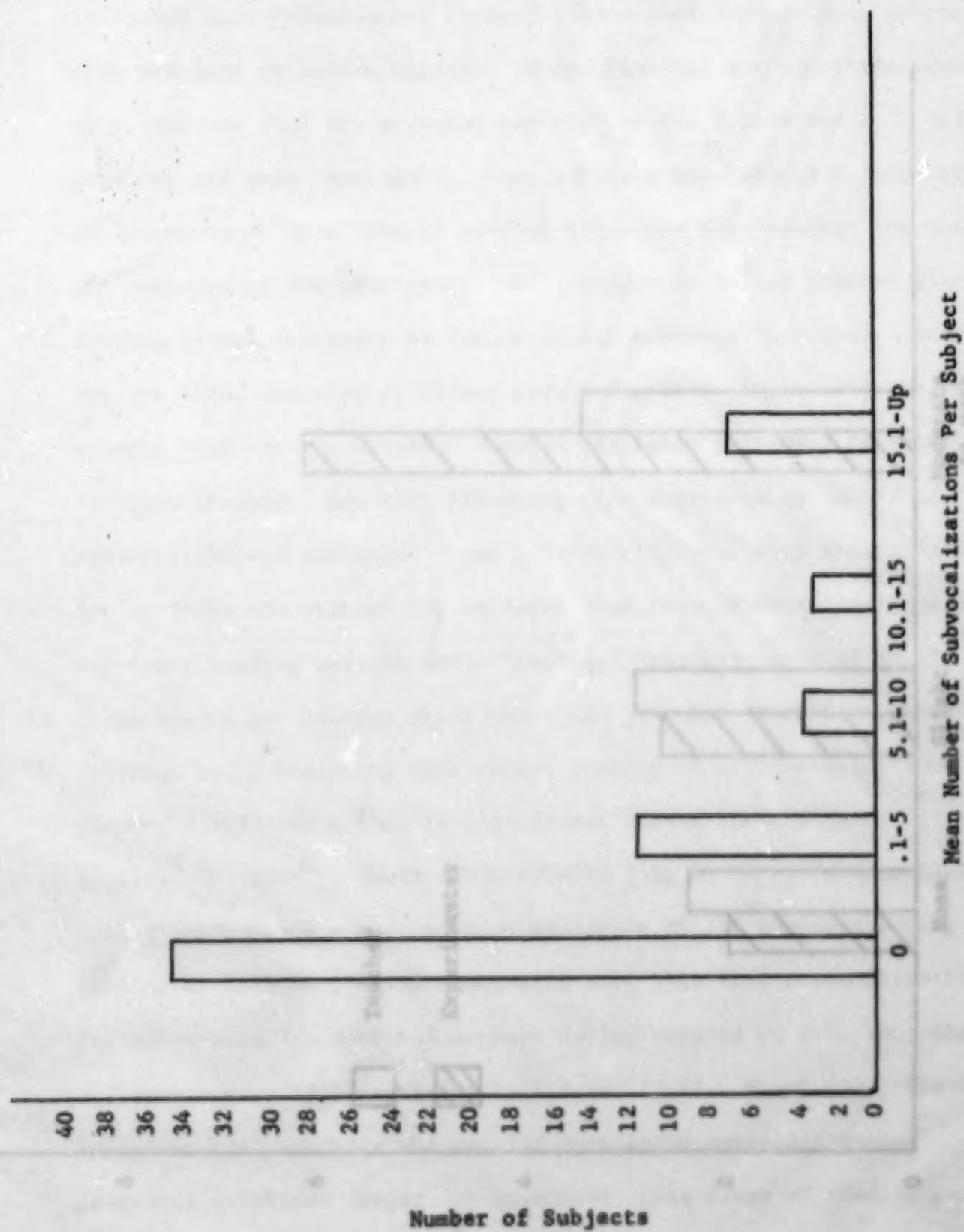


Fig. 21. Mean number of subvocalizations per subject obtained during reading and periods (Experiment II).

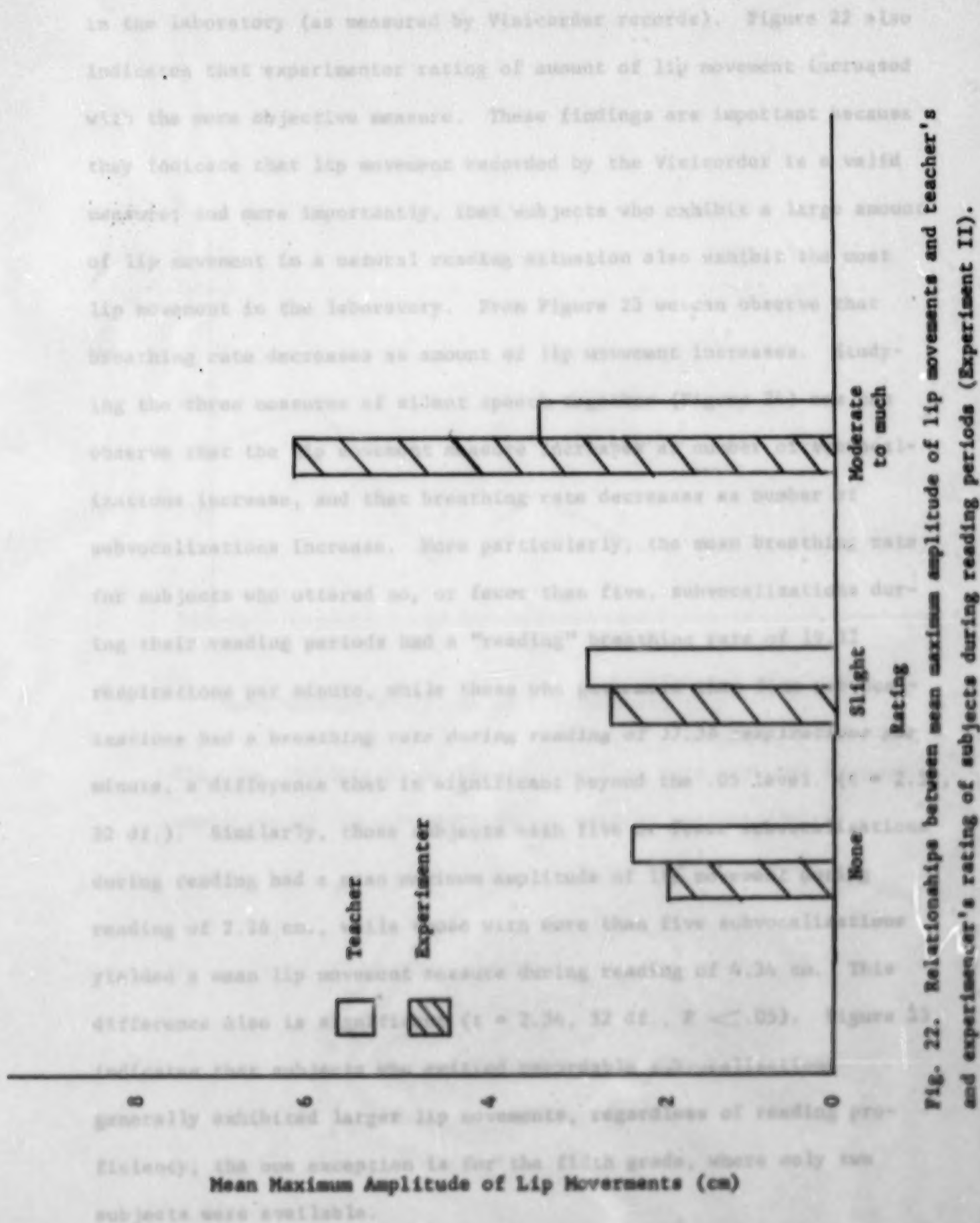


Fig. 22. Relationships between mean maximum amplitude of lip movements and teacher's and experimenter's rating of subjects during reading periods (Experiment II).

in the laboratory (as measured by Visicorder records). Figure 22 also indicates that experimenter rating of amount of lip movement increased with the more objective measure. These findings are important because they indicate that lip movement recorded by the Visicorder is a valid measure; and more importantly, that subjects who exhibit a large amount of lip movement in a natural reading situation also exhibit the most lip movement in the laboratory. From Figure 23 we can observe that breathing rate decreases as amount of lip movement increases. Studying the three measures of silent speech together (Figure 24) one can observe that the lip movement measure increases as number of subvocalizations increase, and that breathing rate decreases as number of subvocalizations increase. More particularly, the mean breathing rate for subjects who uttered no, or fewer than five, subvocalizations during their reading periods had a "reading" breathing rate of 19.12 respirations per minute, while those who gave more than five subvocalizations had a mean breathing rate during reading of 17.54 respirations per minute, a difference that is significant beyond the .05 level. ($t = 2.59$, 32 df.). Similarly, those subjects with five or fewer subvocalizations during reading had a mean maximum amplitude of lip movement during reading of 2.26 cm., while those with more than five subvocalizations yielded a mean lip movement measure during reading of 4.34 cm. This difference also is significant ($t = 2.34$, 32 df., $P < .05$). Figure 25 indicates that subjects who emitted recordable subvocalizations generally exhibited larger lip movements, regardless of reading proficiency; the one exception is for the fifth grade, where only two subjects were available.

The data for one subject are particularly interesting (Figure 26).

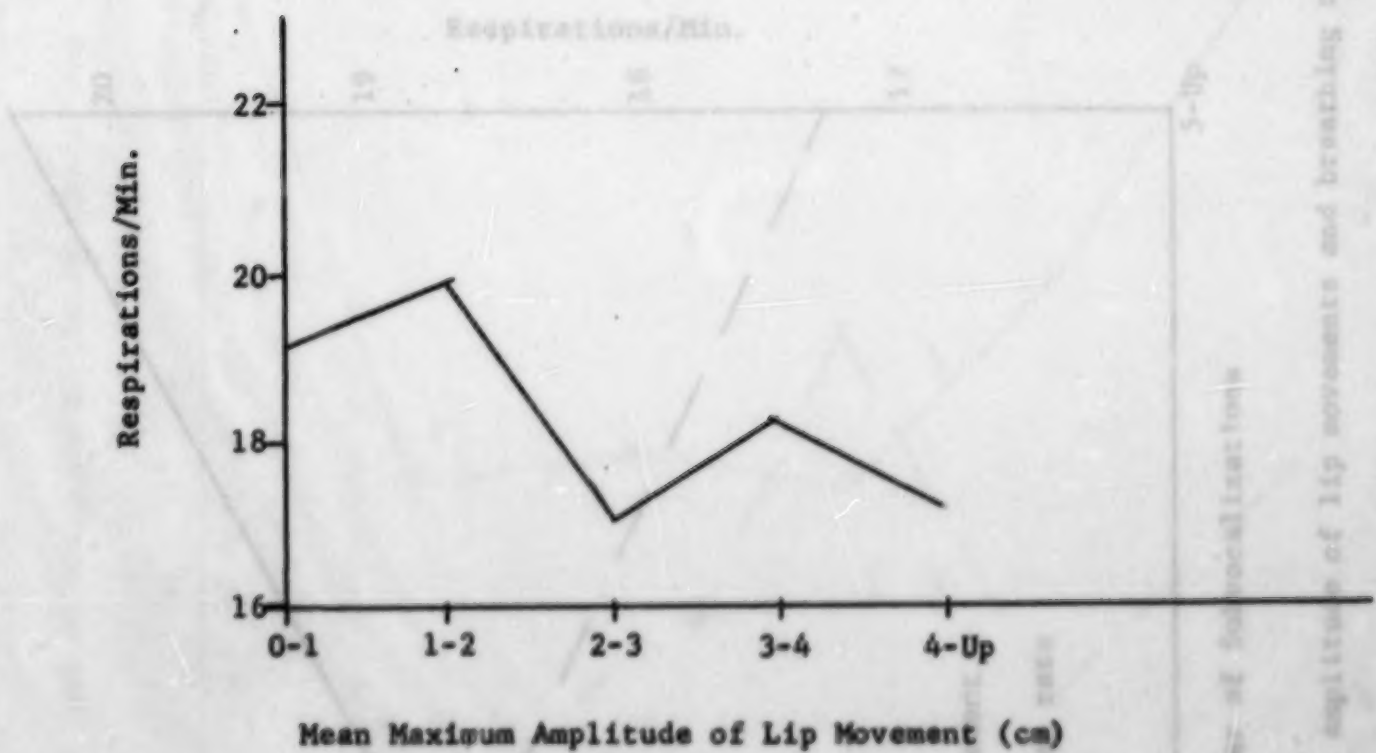


Fig. 23. Relationship between breathing rate and mean maximum amplitude of lip movements during reading periods.

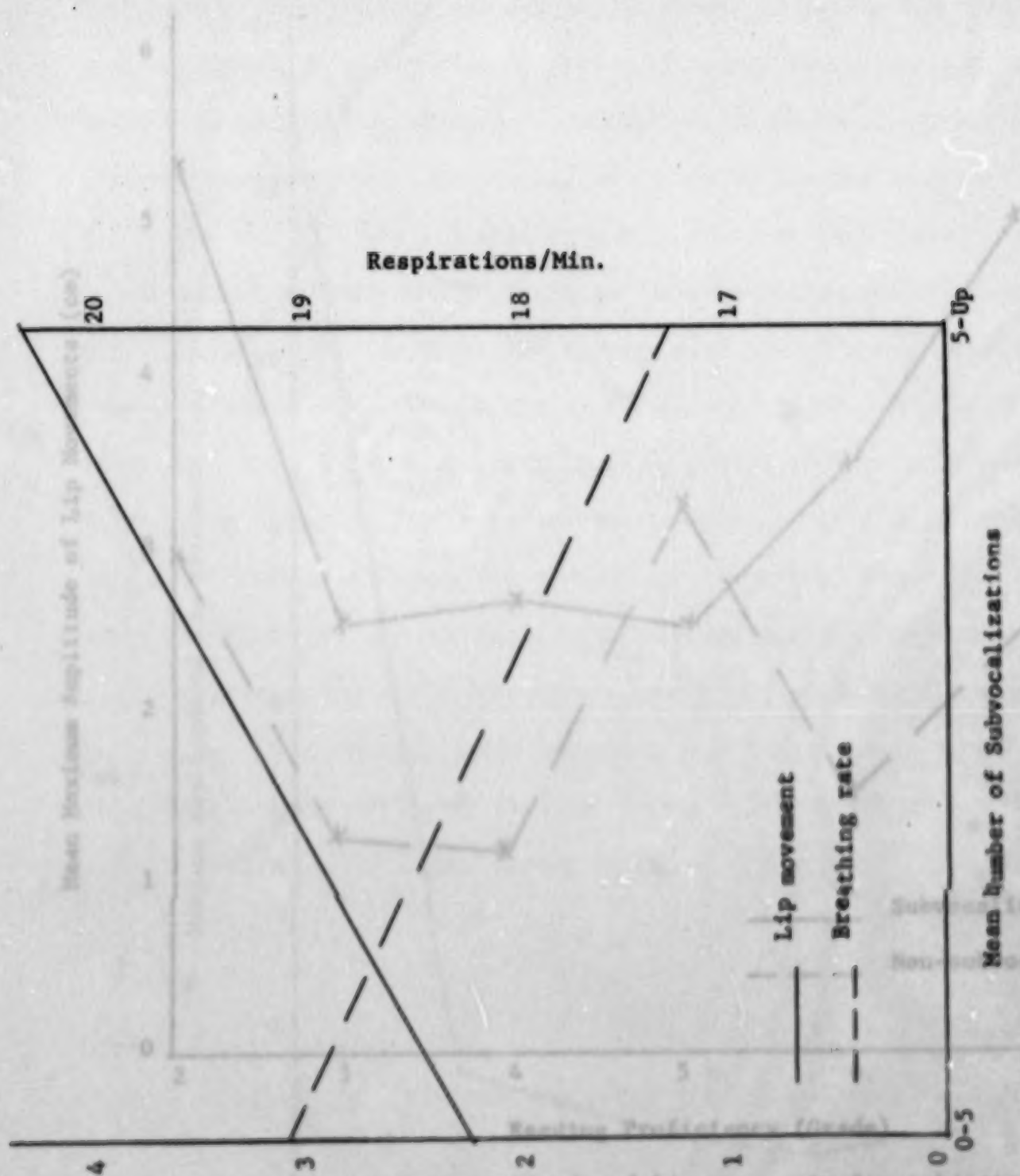


Fig. 24. Mean maximum amplitude of lip movements and breathing rate as functions of mean number of subvocalizations (Experiment II).

Fig. 25. Mean maximum amplitude of lip movements for subjects who subvocalized and for subjects who did not subvocalize during reading periods plotted as a function of reading proficiency (Experiment II).

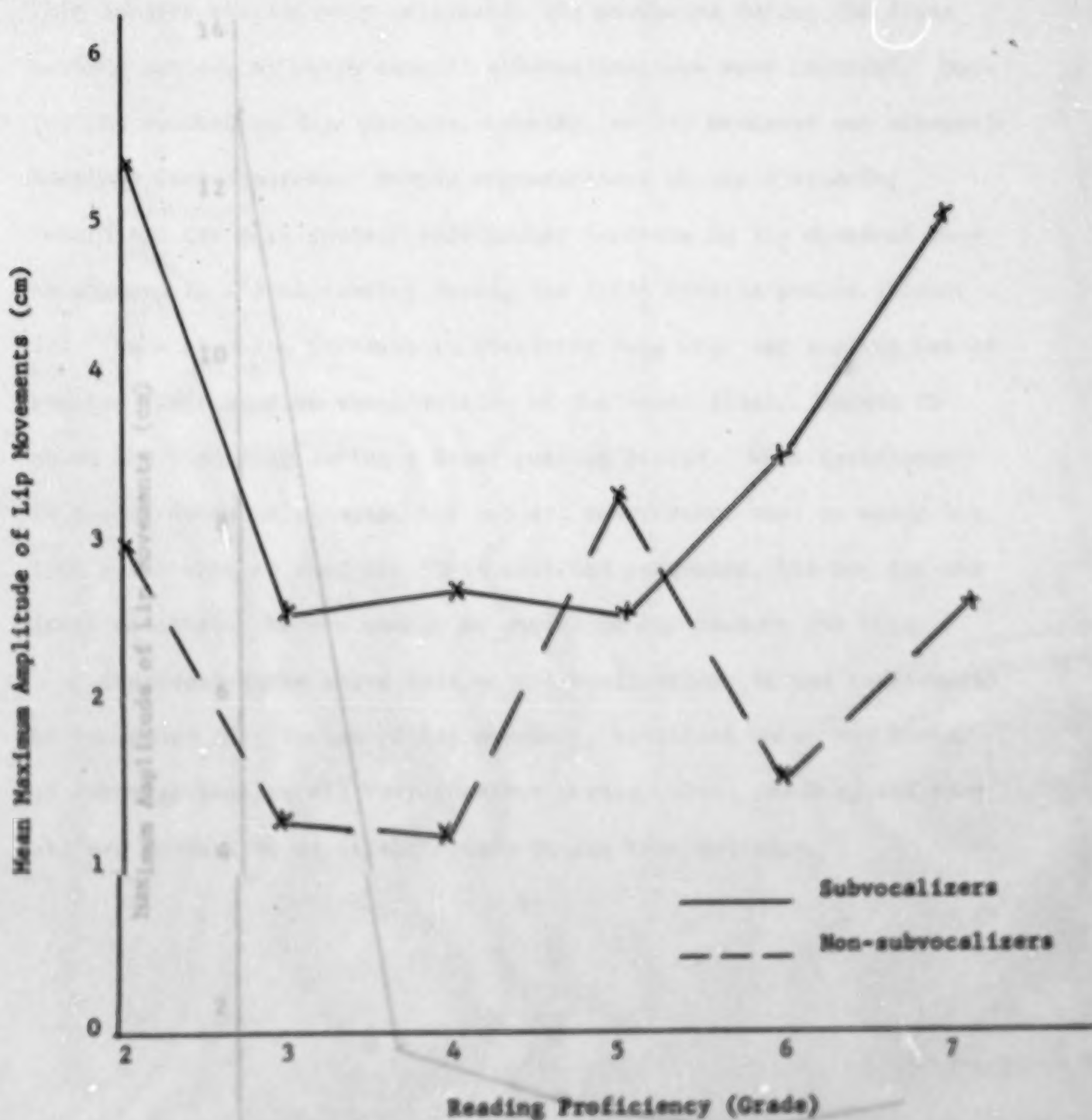


Fig. 25. Mean maximum amplitude of lip movements for subjects who subvocalized and for subjects who did not subvocalize during reading periods plotted as a function of reading proficiency (Experiment II).

Fig. 26. Amount of lip movement for S1 as a function of reading period. During reading period #1 he omitted 15 subvocalizations, but failed to subvocalize during periods 2-5 (Experiment II).

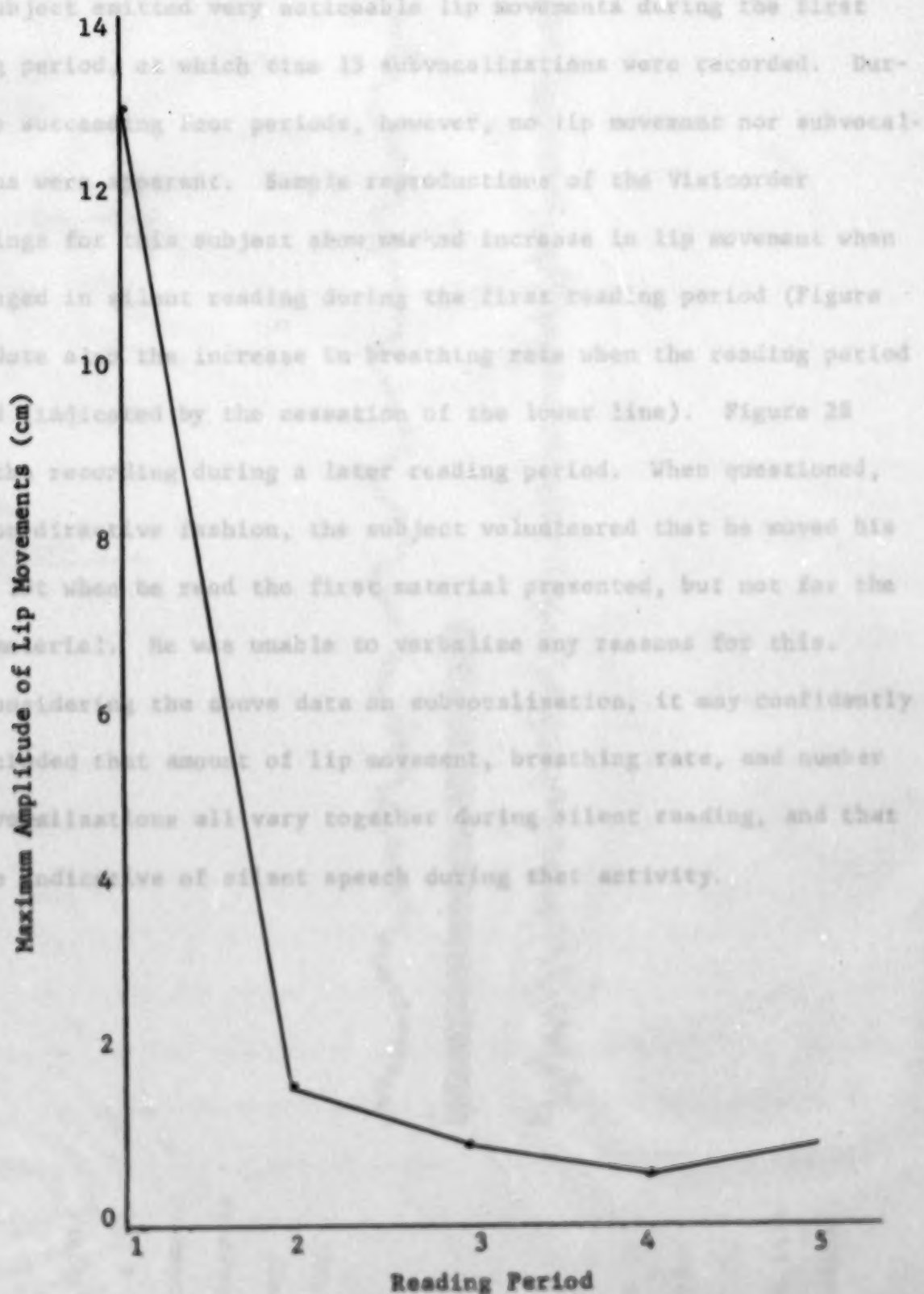


Fig. 26. Amount of lip movement for S#39 as a function of reading period. During reading period #1 he emitted 15 subvocalizations, but failed to subvocalize during periods 2-5 (Experiment II).

This subject emitted very noticeable lip movements during the first reading period, at which time 15 subvocalizations were recorded. During the succeeding four periods, however, no lip movement nor subvocalizations were apparent. Sample reproductions of the Visicorder recordings for this subject show marked increase in lip movement when he engaged in silent reading during the first reading period (Figure 27). Note also the increase in breathing rate when the reading period started (indicated by the cessation of the lower line). Figure 28 shows the recording during a later reading period. When questioned, in a non-directive fashion, the subject volunteered that he moved his lips a lot when he read the first material presented, but not for the later material. He was unable to verbalize any reasons for this.

Considering the above data on subvocalization, it may confidently be concluded that amount of lip movement, breathing rate, and number of subvocalizations all vary together during silent reading, and that all are indicative of silent speech during that activity.

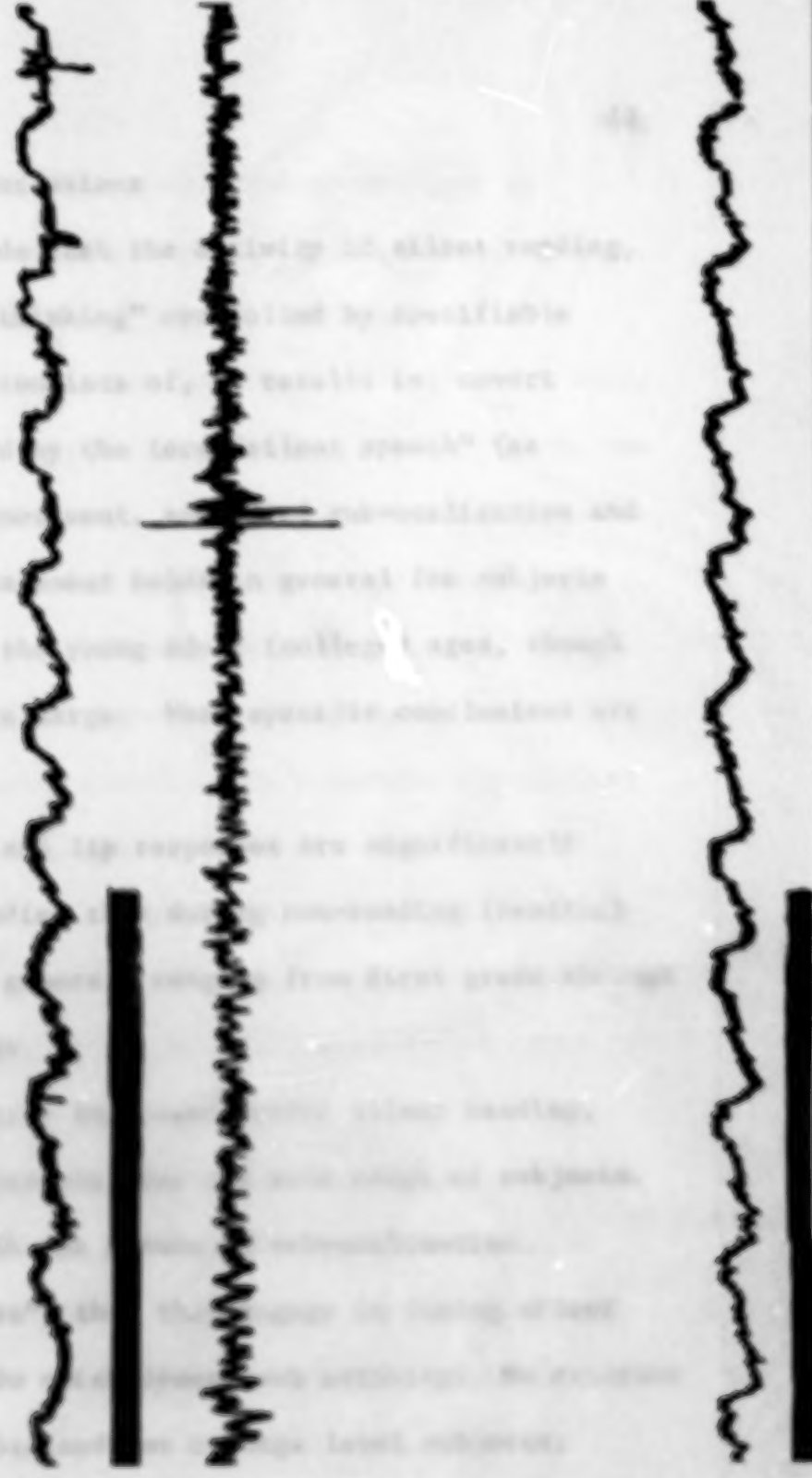
Fig. 27. Tracing of E #30 for first reading period. The solid straight line indicates the vest-log, pre-ventral period; its termination is when the subject commenced reading. Observe the notable increase of lip movement (upper tracing) and the increase of the breathing rate (lower tracing) when silent reading started.

Fig. 28. Tracing of E #30 during a later reading period when, in contrast to Fig. 27, little or no silent speech is apparent during silent reading.

Fig. 27. Tracing of $\Sigma \theta_{39}$ for first reading period. The solid straight line indicates the resting, pre-control period; its termination is when the subject commenced reading. Observe the sizable increase of lip movement (upper tracing) and the increase of the breathing rate (lower tracing) when silent reading started.



Fig. 28. Tracing of $\Sigma \theta_{39}$ during a later reading period when, in contrast to Fig. 27, little or no silent speech is apparent during silent reading.



Conclusions

1. We may confidently conclude that the activity of silent reading, which may be considered "thinking" controlled by specifiable external stimuli, either consists of, or results in covert language responses denoted by the term "silent speech" (as measured by lip and chin movement, amplified subvocalization and breathing rate). This statement holds in general for subjects ranging from six through the young adult (college) ages, though individual differences are large. More specific conclusions are as follows.
2. Amplitude of covert chin and lip responses are significantly greater during silent reading than during non-reading (resting) periods for subjects (in general) ranging from first grade through college educational levels.
3. Breathing rate significantly increases during silent reading, compared to non-reading periods, for the same range of subjects.
4. Children differ greatly in the amount of subvocalization ("whispering to themselves") that they engage in during silent reading -- the majority do not evidence such activity. No evidence of subvocalization was obtained for college level subjects.
5. College subjects studying a foreign language (French) exhibit silent speech (increased lip movement and increased breathing rate) when reading both English and French, but do not differ in the amount of silent speech as a function of the language read.
6. Amount of silent speech (chin movement) increased significantly as the material read increased in difficulty in one experiment, but this finding was not statistically confirmed in a second using

- lip movement as a measure. These results were obtained on children -- no evidence of difficulty of material affecting amount of silent speech was found for college students.
7. While the data were suggestive that amount of silent speech (chin and lip movement) decreases as reading proficiency increases, the results failed to reach acceptable levels of statistical significance. This statement holds for both children and for college students reading English and a foreign language.
 8. Respiration rate decreases as chronological age increases.
 9. Respiration rate decreases as school grade placement varies from the first through the fifth grade.
 10. Respiration rate increases as a function of intelligence. While the data suggest that this measure of silent speech increases during silent reading, they do not reach acceptable levels of statistical significance.
 11. Teacher ratings of amount of lip movement during classroom reading increase with amplitude of lip movement measured during reading periods in the laboratory, indicating similarity of the phenomenon of silent speech in natural and in experimental situations.
 12. As amount of lip movement during reading periods increases, breathing rate decreases.
 13. As number of subvocalizations increases, amount of lip movement significantly increases, and respiration rate significantly decreases. The relationships among these three measures of silent speech indicate that they are all valid measures of the phenomenon.

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